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Original article

Experience of using internal fixation in the treatment of patients with inflammatory complications of mandibular fractures: a retrospective study

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Abstract: *Study goal* — To evaluate the efficacy of plate osteosynthesis in the treatment of patients with inflammatory complications of mandibular fractures on a large sample.
Material and Methods — We conducted a retrospective analysis of medical records collected over 15 years in a group of patients with inflammatory complications of mandibular fractures. The analysis included medical records of patients who underwent plate osteosynthesis operations performed according to the surgical algorithm adopted in the clinic, in combination with a simultaneous directed antibacterial effect on the microflora of the pathological focus and osteoplastic replacement of defects. We identified 164 medical records meeting the search criteria distributed among two study groups. Group A included hospitalized patients with developed abscesses and phlegmons of soft tissues surrounding the fracture area. For them, two-stage surgical intervention was performed. Group B consisted of patients who had no suppurative process in soft tissues, which allowed them undergoing one-stage surgical treatment.
Results — Good, satisfactory, and unsatisfactory surgical outcomes were obtained in 82.6%, 14.9%, and 2.4% of the patients, respectively. The differences between the comparison groups were not statistically significant.
Conclusion — The clinical effectiveness of an integrated approach to the surgical treatment of patients with inflammatory complications of mandibular fractures, based on providing stable fixation of connected fragments as a critical factor in bone wound healing via osteosynthesis, was confirmed on large samples in both comparison groups.

Keywords: mandible, inflammatory complications of fractures, osteosynthesis, osteomyelitis.

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Introduction

Mandibular fractures are among the most common types of traumatic injuries of the facial bones, accounting for up to 70-80% of those, according to some authors [1-3]. This type of traumatic injuries is also associated with the highest risk of complications, primarily of inflammatory nature, as most of such fractures are open due to their communication with the oral cavity.

Over three decades ago, V.A. Kozlov reported an incidence of traumatic mandibular osteomyelitis at the level of 10-12% [4]. However, even now, according to current clinical guidelines (treatment protocols) adopted by the Russian Dental Association in 2016, the risk of inflammatory complications in closed and open mandibular fractures is 8% and 10%, respectively [5]. This is consistent with the published data of the previous decade, according to which inflammation in the mandibular fracture area may occur in 6.5-27% of cases [6-9]. In the study by C.L. Chen [9], inflammatory complications were noted in 52.4% of the total number of postoperative complications that required revision surgery. In remaining cases, there was no fracture healing, which was also most likely related to inflammation. In other words, despite the achievements of the past decades and introduction of novel surgical technologies, such complications remain an urgent issue of the clinical practice.

The following factors predisposing to the development of inflammation were discussed by various authors: the presence of teeth in the fracture line [7, 10-12], periapical infection sites near the injury [13], the severity of a traumatic injury, the nature and number of fracture lines and their communication with the oral cavity [14, 15], alcohol abuse, substance abuse, smoking [8, 9, 16, 17], late jaw immobilization [7, 18, 19], and the method of bone fragment fixation [9, 20]. The frequency of complications does not appear to be largely dependent on the used antimicrobial therapy regimen [7, 10, 16, 21]. Anaerobic microflora of the oral cavity plays an important role in the development of traumatic osteomyelitis of the mandible [22, 23]. These factors contribute to the severity of abscesses and phlegmons that develop in the soft tissues adjacent to the fracture and are sometimes life-threatening, and to the

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persistence of bone tissue inflammation, which is often recurrent. U. Ertas et al. [14] described the case of traumatic mandibular osteomyelitis persisting for 20 years after the injury.

Most recommendations for the treatment of infected mandibular fractures mainly concern the issue of improving the effects of medicamentous or physical therapy of the infection site [24–27]. However, these factors are not of paramount importance. If there is a persistent mobility of fragments caused by masticatory muscles, it will result in continuous suction of the oral fluid containing pathogenic microflora into the bone wound. Consequently, a much more relevant issue, in our opinion, is selecting the method of bone fragment fixation in the presence of inflammation. This issue has not been elucidated so far, and there is still no consensus regarding it [28]. Available reports are rare and contradictory. The techniques of plate and screw fixation for the treatment of mandibular fractures, which could provide stable connection of mandibular fragments, are widely used in clinical practice. However, the relevance of placing such devices "directly into the pus" (B. Weber [29]) is debatable. According to various studies, new surgeries to remove internal fixators located in the area of infected mandibular fractures are required in 2.2% to 27% of the cases [6, 9, 17, 20, 30]. On the other hand, external fixation devices cannot provide sufficient stability of bone fragment fixation [31], which may have a negative impact on the clinical course.

Hence, we conducted a study to evaluate the effectiveness of internal fixation techniques in the treatment of mandibular fractures with inflammatory complications.

Material and Methods

Study design

We conducted a retrospective study of health records of the patients with inflammatory complications after mandibular fractures treated in the Maxillofacial Surgery Clinic of N.I. Pirogov Municipal Clinical Hospital No.1 over a period of 15 years. The diagnoses of bone wound infection or traumatic osteomyelitis were based on the presence of purulent discharge from the fracture line, inflammatory changes in adjacent soft tissues with development of abscesses and phlegmons, formation of fistulas and bone destruction seen on X-rays. The exclusion criteria were as follows: liver cirrhosis, diabetes mellitus requiring continuous high-dose insulin therapy, and pathologic fractures. This patient cohort had a high risk of pronounced immunodeficiency and reduced potential of regenerative tissue as a result of the underlying disease. No surgical treatment algorithm for mandibular fractures was developed to date for this cohort [32]. We analyzed 164 health records meeting the search criteria: of these, 136 (82.9%) were males and 28 (17.1%) were females 18 to 72 years of age. As suggested by the data presented in *Table* 1, inflammatory complications of mandibular fractures were characteristic for all age groups but were more common in patients from 30 to 39 years old. The patient distribution by age groups is shown in *Table* 1 as well.

Plate and screw fixation techniques were employed to ensure the continuity of mandibular bone in all patients enrolled in the study. Because we considered stable bone fragment fixation the factor required for normal bone healing, we practiced early surgical treatment of the patients (including those enrolled in the study). Upon admission to the clinic, in order to prepare for the osteosynthesis operation, the patients underwent primary immobilization of their jaws using intermaxillary fixation to achieve occlusion restoration. The teeth from the fracture area were extracted; the bone wound was revised through the sockets, and free bone fragments or sequesters were removed. If the patient has already been treated before, the applied splints were adjusted if necessary.

The studied patients were distributed between two groups. Group A included hospitalized patients with developed abscesses and phlegmons of soft tissues surrounding the fracture area. For them, we performed two-stage surgical intervention. Upon admission, the adipose tissue spaces were incised and drained. Wounds were treated every day with chlorhexidine-containing antiseptics, and antimicrobial therapy was prescribed according to conventional schemes. After eliminating acute inflammation (manifested in normal body temperature or low-grade fever, stable laboratory test parameters, wound cleaning and granulation tissue development), the main surgery was conducted, provided that there was no clinical evidence of further progression of inflammation in the soft tissues.

Group B consisted of patients who had no suppurative process in soft tissues, which allowed them undergoing one-stage surgical treatment. In the comparison groups, the duration of the period of exudation from the postoperative wound was studied as the main objective feature allowing to evaluate the severity of inflammatory response. The Mann-Whitney criterion was used to verify the validity of differences between quantitative indicators in independent groups. The differences were considered statistically significant at $p \leq 0.05$.

Statistical data processing was carried out using MS Excel software, GraphPad Prism 7. Qualitative indicators are presented in the form of absolute and relative frequencies. Quantitative data in the case of a normal distribution are presented in the form of $M \pm \sigma$, where M is the mean and σ is the standard deviation. In the absence of a normal distribution, the data are presented as a median and 95% confidence interval (95% CI). The comparison of quantitative indicators between the groups was carried out using the Student's criterion (given a normal distribution in both groups) or using Mann-Whitney criterion. The comparison of qualitative indicators between the groups by was performed using the Fisher's exact test and $\chi 2$ test. All differences were considered statistically significant with a probability of at least 95% ($p \leq 0.05$).

Methods of surgical treatment

During the main operation, both intraoral and extraoral approaches were applied. The latter was used in the presence of wounds after the opening of an abscess or phlegmon, fistulas in the mandibular or chin area, large sequestrations, or significant loss of bone mass. If there were enlarged lymph nodes, they were removed in order to avoid possible postoperative inflammatory complications. Scar and granulation tissue adhesions were removed.

Table 1. Distribution of patients with inflammatory complications of mandibular fractures by age groups

Age groups	*Number of patients in the group*	*Percentage (%)*
<20 years	7	4.26
20-29 years	32	19.5
30-39 years	63	38.4
40-49 years	45	27.4
>50 years	17	10.4

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Figure 1. A manual drill with an original limiter developed for making holes for monocortical screw placement. It is attached to the handpiece of the dental screwdriver with a locking connector.

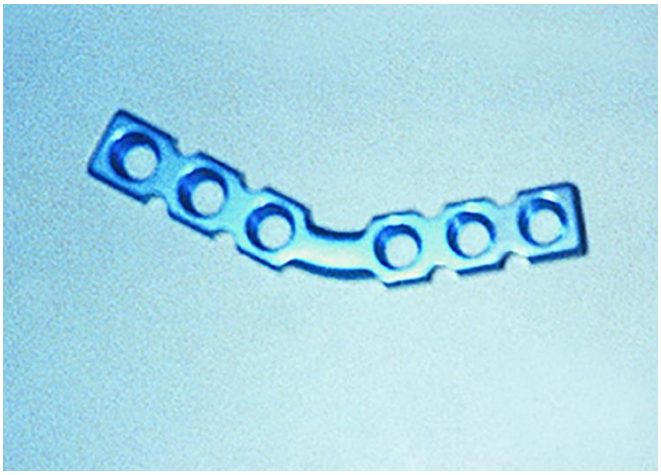

Figure 2. Original reconstructive plate for fixation of anterior angular fractures of the lower jaw at the border of the angle and the body.

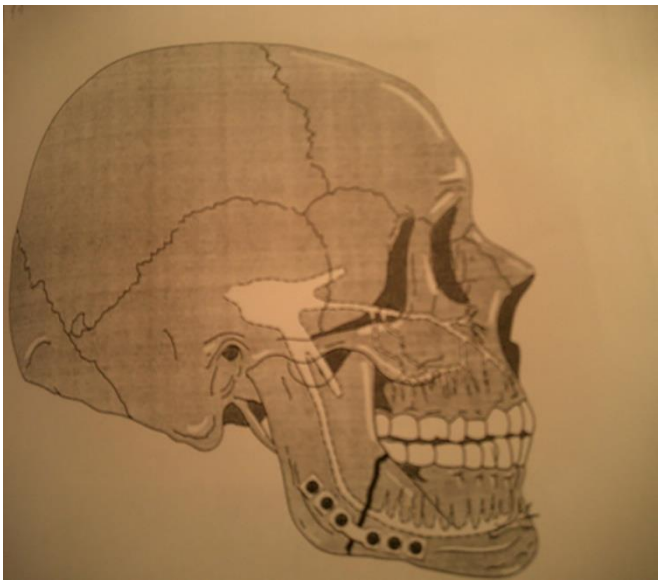

Figure 3. Schematic diagram of the placement of our specially designed plate for fixation of anterior angular fractures located in front of the angle.

During the bone wound examination, sequesters, scar and granulation tissue fragments, along with periosteal deposits, were removed from the bone gap, as they could contain microabscesses. Additionally, the areas of osteonecrosis along the bone fragments were removed until there were signs of bleeding. After that, pulsed lavage with antiseptic solutions was applied for wound cleansing. Before fixing the bone fragments, we made sure that the occlusion was corrected using the appropriate dental splints. We believed it was an indispensable procedure to prevent malocclusion, as it is impossible to achieve correct occlusion using elastic bands in the postoperative period in the curse of performing stable mandibular osteosynthesis [33].

To ensure stable fixation of mandibular bone fragments, we used plates and screws manufactured by Conmet (Russia).

In cases when the bone defect after removal of abnormal tissues were local or absent (in infected wounds), miniplates were applied for mandibular bone fixation. The surgical technique was slightly modified taking into account the results of our previous studies [33]. Two miniplates were applied not only when the fracture line was in the frontal region of the mandible but also when one of the fragments had no teeth (or too few teeth). One miniplate fixed with bicortical screws was placed along the inferior margin of the mandibular bone; the second one was fixed with monocortical screws along the field line. To avoid damage to the teeth roots and inferior alveolar nerve canal, we used a manual drill with an original limiter (*Figure* 1).

In cases where the resulting bone defect was not limited to a small fragment of one cortical plate, but was through, occupying a large area of bone tissue, reconstructive plates with bicortical screws were used for fixation. These devices were applied according to the standard technique using special wrenches and a curved template. The recommended number of screws is three (or at least two) for each bone fragment, provided that the middle ones are located at a distance of at least 5 mm from the defect and are fixed in healthy bone.

In case of angular fractures, the bone was fixed with plates of two types. In patients with so called central angle fractures, commercially available orthodontic angular plates (Conmet, Russia) with an internal angle of 122º were used. In cases when the fracture line was located at the border between the angle and the body of the mandible, we had to increase the angle of these plates manually during the surgery to avoid damage to the teeth roots and the canal of inferior alveolar nerve. This increased the duration of the operation and led to the development of microcracks, which could further expand under functional loading, leading to plate fractures. The maximum permissible plate bending angle recommended by the manufacturers is 150º. One of the authors suggested using a plate with an internal angle of 145º, which prevents excessive plate bending in the course of its adaptation. The latter is required to ensure that plate holes are located closer to the inferior and posterior margins of the mandibular bone, so that there is no risk of the neurovascular bundle injury [34]. In such case, if the fracture lines are located on the border between the angle and the body of the mandible, the plate angles are within the range of 140º-150º (*Figures* 2, 3).

Before the operation and in the postoperative period, the patients received antimicrobial treatment and antiedema therapy. Antibiotics were initially prescribed parenterally, then patients received them per os.

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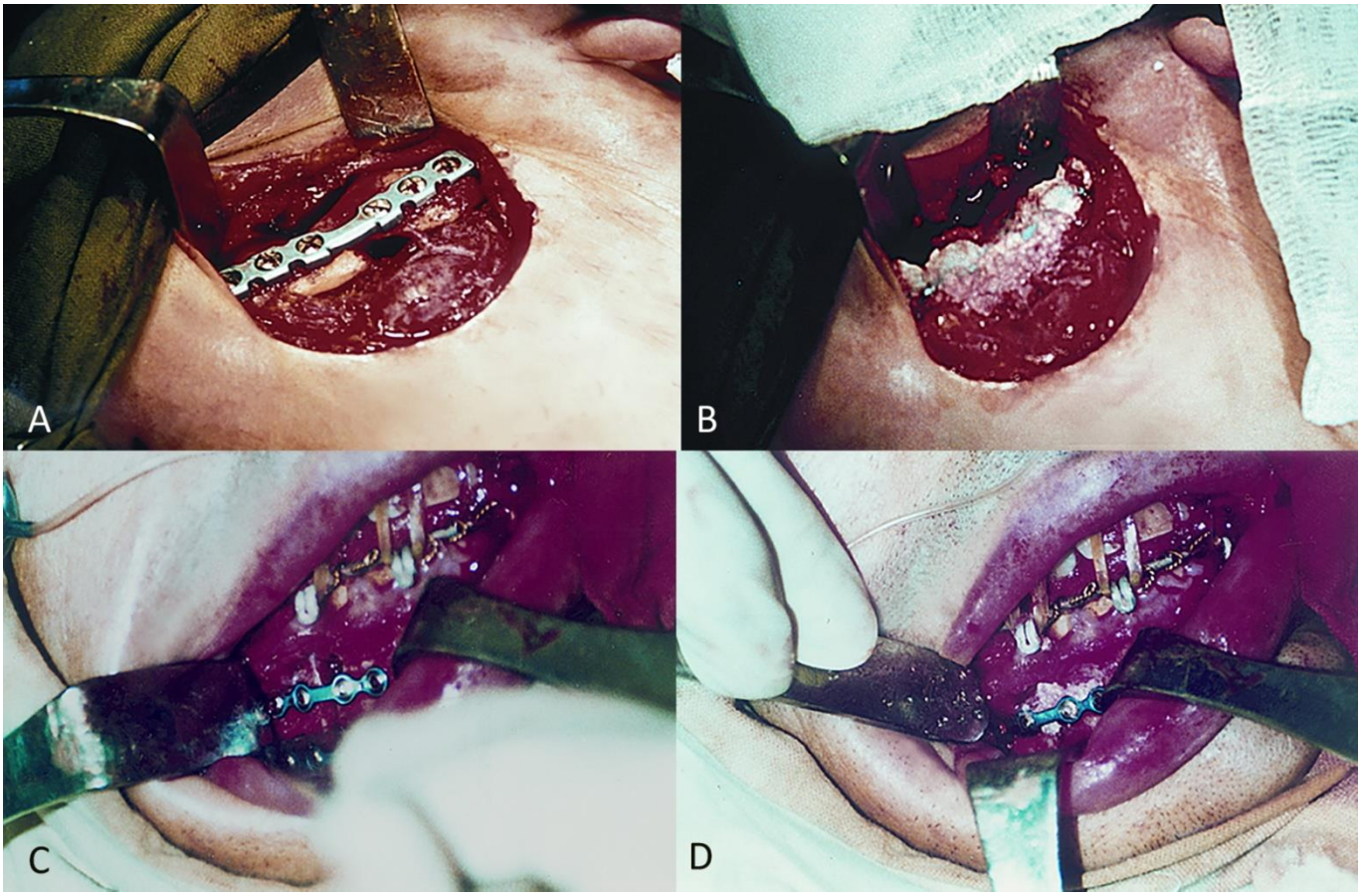

Figure 4. Bone osteosynthesis of the mandible, in combination with implantation of nanocrystalline hydroxyapatite compositions with antimicrobial drugs into the cavity of defects formed after sequestrectomy. A – Bone fragment fixation in a patient with traumatic osteomyelitis of the mandibular angle using our specially designed plate. Surgical wound view. Along the inferior margin, there is a bone defect formed after removal of the necrotic bone tissue and sequesters. B – The bone defect and the area of plate implantation are filled with nanocrystalline hydroxyapatite compositions with antimicrobial components. C – Fracture of the lower jaw in the area of the mental foramen, complicated by osteomyelitis. Osteosynthesis with miniplates was performed from intraoral access. The resulting bone defect is observed after removal of the sequester. D – View after filling the bone defect with nanocrystalline hydroxyapatite compositions with antimicrobial components.

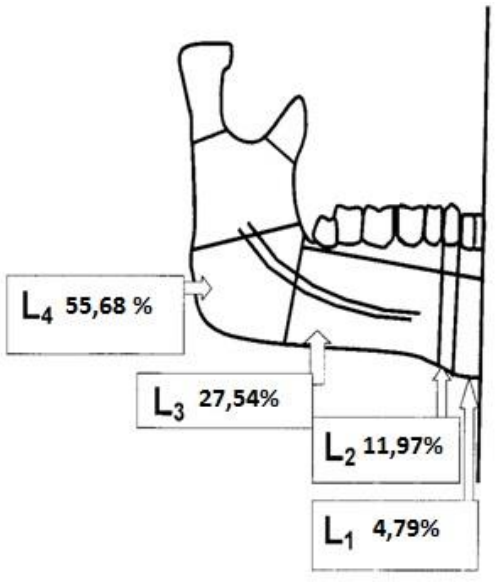

Figure 5. Distribution of mandibular fracture lines by site in patients with inflammatory complications.

In cases of cavity bone defect formation, after sequestrectomy or removal of free-lying bone fragments, they were filled with bone replacement material – nanocrystalline hydroxyapatite with antimicrobial components (Ostim, Russia), which were continuously released directly into the area of implantation at concentrations exceeding the minimum inhibitory concentration, MIC_{90}, for most types of pathogenic microflora [35] (*Figure* 4). Unlike autografts and allografts, hydroxyapatite cannot be a breeding ground for the reproduction of microorganisms.

After discharge from the hospital, the patients were under the supervision of a physiotherapist on an outpatient basis, and an outpatient medical record was maintained. The maximum follow-up period was 1 year, which was necessary for the complete elimination of the pathogen in patients with osteomyelitis in accordance with the EMA recommendations for the evaluation of anti-infective agents [36].

This study was approved by the local ethics committee at the First Moscow State Medical University (Sechenov University). All procedures performed in this study were in compliance with the ethical standards of the institutional research committee and with 1964 Declaration of Helsinki.

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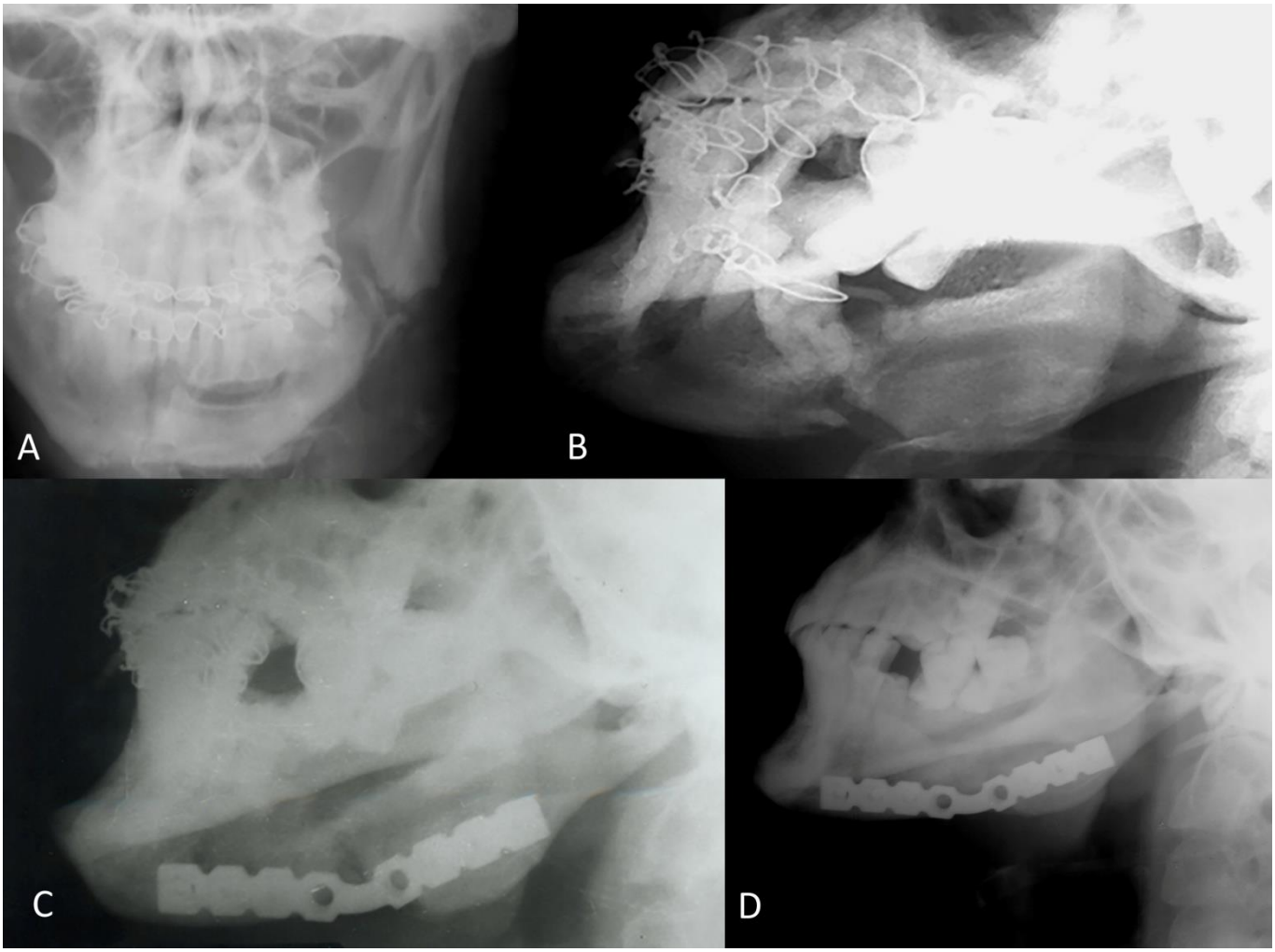

Figure 6. Restoration of lost bone structures in patient E with traumatic osteomyelitis of the mandible. A - Results of X-ray examination of male patient E. who was admitted to the hospital with symptoms of acute inflammation. There are clinical signs of a phlegmon in the submandibular region on the left, and radiographic signs of traumatic osteomyelitis in the area of the left mandibular angle, accompanied by sequester formation. The patient had previously undergone maxillomandibular splinting, while no surgical procedures were performed. B – Results performed the next day. A day earlier, the submandibular phlegmon was incised, the bone wound was revised, and a large sequester was removed. After the revision, the 4.8 tooth was extracted. C – Results three months after the revision surgery with external bone fixation and implantation of nanocrystalline hydroxyapatite compositions with antimicrobial components. D – Results months after the surgery. The bone defect area is completely filled with newly formed bone tissue.

Results

Overall condition of patients undergoing surgery was satisfactory or of a moderate severity grade; 65 patients (39.6%) were diagnosed with a concomitant traumatic brain injury, which supported its role in the pathogenesis of inflammatory complications of mandibular fractures; 10 patients (6.1%) had multiple maxillofacial traumata; 44 patients (26.8%) had concomitant disorders, the most common of which were cardiovascular disorders (59%). Other conditions included respiratory, gastrointestinal and genitourinary disorders. In some patients, several body systems were affected.

Three patients with bilateral mandibular fractures had inflammatory complications on both sides. Thus, the total number of fracture lines with signs of inflammation was 167. Their distribution by site is shown in *Figure* 5. The greatest number of inflammatory complications in mandibular fractures was observed in the angle area, less in the lateral parts of the body, followed by the canine area. The complications developed least often in the area of incisors.

Dental trauma splint devices could not be applied in 14 patients (8.5%) due to the loss of teeth. Soft tissue abscesses and phlegmons in adjacent areas were observed in 66 (40.24%) patients. One patient with bilateral mandibular fractures had bilateral abscesses.

Reconstruction plates were used for mandibular bone fragment fixation in 61 cases (36.5% of the total number of surgically treated infected fractures). In other cases (n=106; 63.4%), miniplates were applied. In 32 cases (19.5% of the total number of patients included in the study), surgical treatment had to be also used for mandibular fractures exhibiting no signs of inflammation. In most cases, these surgical procedures were performed simultaneously with the main surgery; however, they were not included in the study and were not analyzed.

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Table 2. Results of surgical treatment of mandibular fractures with inflammatory complications in study subjects

Outcome	*Number of surgical procedures (n=167)*	*Percentage (%)*
Good	138	82.6
Satisfactory	25	14.9
Unsatisfactory	4	2.4

Table 3. Comparative characteristics of treatment results in comparison groups

Treatment results	*Group A* Number of operations N=67	*Group B* Number of operations N=100
Good	51 (76.1 %)	88 (88 %)
Satisfactory	13 (19.4 %)	11 (11 %)
Unsatisfactory	3 (4.5 %)	1 (1 %)

The differences are not statistically significant (p=0.097). Group A: patients, whose osteosynthesis surgery was preceded by suppurative changes in surrounding soft tissues. Group B: patients in whom such phenomena were not observed.

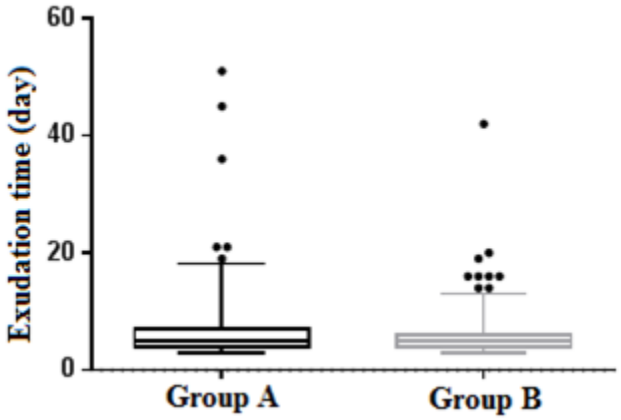

Figure 7. Duration of exudation (including cases associated with recurrence of inflammation) in the postoperative period in patients of comparison groups. The differences are not statistically significant (p=0.677). Group A: patients, whose osteosynthesis surgery was preceded by suppurative changes in surrounding soft tissues. Group B: patients in whom such phenomena were not observed.

Use of standard osteosynthesis technique for treating mandibular fractures significantly facilitated surgical procedure and allowed reducing its duration. The surgery did not result in deterioration of the general condition in any of the patients.

The treatment outcome was considered good if there was no wound discharge on days 3-7, and the postoperative period was uncomplicated with elimination of inflammatory manifestations and restoration of the anatomical integrity and function of the mandibular bone. Antibacterial therapy in such patients lasted over no more than 5-7 days after the osteosynthesis.

The outcome was classified as satisfactory in the presence of wound exudate discharge for more than 7 days and partial wound divergence followed by secondary wound tension, development of hematomas, and recurrent inflammatory manifestations, which were stopped by continued antimicrobial therapy and repeated drainage. No fixation device removal was required, and clinical recovery was achieved after respective therapeutic procedures.

The treatment outcome was considered unsatisfactory in case of progressive inflammation, fistula formation, continuing mobility of the bone fragments implying the lack of complete bone healing. In this case, repeated surgical interventions were required to remove the metal fixators. All types of treatment outcomes are presented in *Table* 2.

Of the patients with unsatisfactory results of surgical treatment (n=4), 3 cases had the fracture localized in the angle area, and 1 case had the fracture in the lateral parts of the lower jaw body. In one of these observations, miniplates were used for a fracture in the area of the angle of the mandible, despite a significant defect in the external cortical plate, which we interpreted as inadequate choice of a fixator, which was the likely cause of the complication.

The greatest number of satisfactory outcomes were noted in the area of the angle of the lower jaw: 17 patients (18.3% of fractures in these localizations). In L3 and L2 sectors, there were 6 (13.04%) and 2 (10%) satisfactory results, respectively. All other cases were classified as good results.

Figure 8. Occlusion in patient S. after the attempt of traumatic osteomyelitis treatment using an external fixator.

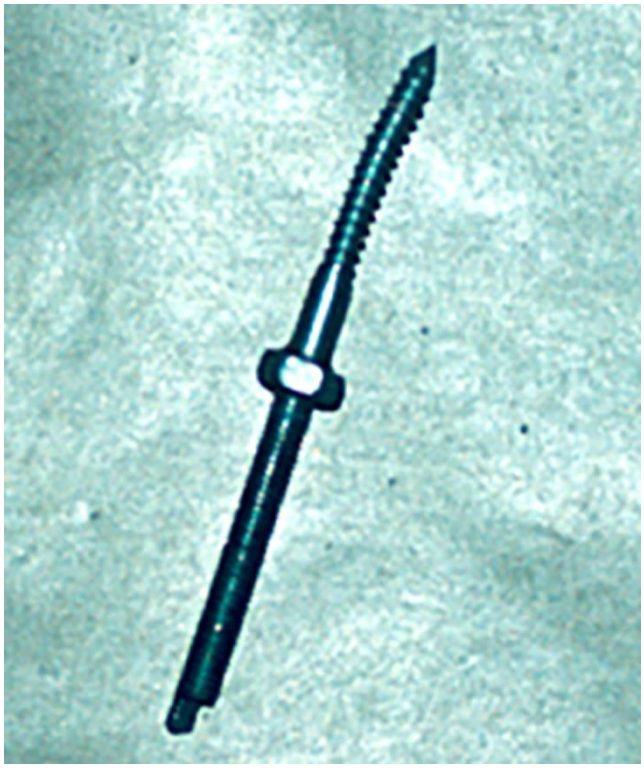

Figure 9. Deformities of external fixator pin after the attempted reduction in patient S.

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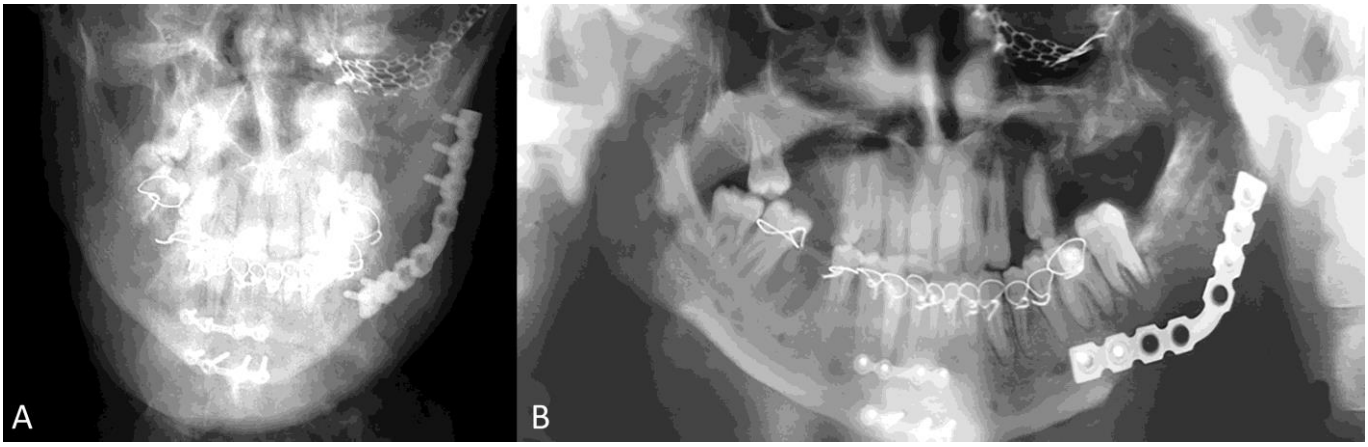

Figure 10. Results of X-ray examination of patient Sh. A – After the bone wound revision and bilateral osteosynthesis of the mandible (reconstructive orbital surgery was performed earlier at another facility). B – The orthopantomogram of patient Sh. following bone wound revision and bilateral osteosynthesis of the mandible.

The application of nanocrystalline hydroxyapatite compositions to the bone defects was not technically difficult and did not require any substantial prolongation of the surgical procedure. However, these substances were used in the form of an aqueous paste, the fluidity of which caused partial loss and elimination of the substance with wound discharge in the early postoperative period. No cases of nanocrystalline hydroxyapatite intolerance were observed. There was rapid restoration of bone structures in the presence of this bone substitute (*Figure* 6), which confirmed its effectiveness in surgical treatment of this patient cohort.

Comparative results of treatment in patients of Group A (where osteosynthesis surgery was preceded by the development of abscesses and phlegmon of the surrounding soft tissues) and Group B (where suppurative phenomena of soft tissues were not observed) are presented in *Table* 3.

Comparing the results of treatment between the comparison groups revealed high frequency of good outcomes among patients without suppurative changes in soft tissues (88% vs. 76.1%), but this difference was not statistically significant (p=0.097).

In the group of patients with previous suppurative changes, the duration of exudation ranged 3-51 days and amounted to 5 (95%CI 3-30) days, while in patients without suppurative phenomena, it varied from 3 to 42 days, on average 5 (95%CI 3-16) days. Tests for the normality of the distribution (Pearson test, Shapiro-Wilk test) yielded no normality; hence, nonparametric statistical methods were used. For visual analysis, the data range diagram in the form of a boxplot is presented in *Figure* 7. The lengths of whiskers are represented by the 9th and 91st percentiles. The diagram demonstrates agreement between the groups in medians and lower quartiles, and slight discrepancy in the readings of the upper quartiles. There is also a greater number of outliers in Group A. When comparing quantitative indicators between the groups via the Mann-Whitney test, no statistically significant differences were established regarding the duration of exudation in patients with previous suppuration vs. those without it (p=0.677).

Discussion

As shown in our study, inflammatory complications are very likely when the fracture line is located in the dentition due to its communication with the oral cavity. In case of a combination of bone injuries and surrounding soft tissues, inflammatory complications in the area of other fractures may develop, but such cases are extremely rare and were not included in this study. multiple injuries, combined injuries, and concomitant diseases. If the patient condition is severe because of combined trauma, it may be necessary to delay the repair of a mandibular fracture, which, against the background of developing immunological disorders, also contributes to the development of complications. As expected, the highest frequency of complications was observed in patients with mandibular angle fractures, i.e., in the area of direct attachment of masticatory muscles (the masseter and medial pterygoid). Since in this case, a small fragment has no teeth, it is impossible to ensure adequate immobilization of the jaws using splinting devices. In the presence of a dislocation of the bone, delayed surgery is very dangerous.

The standard fixation techniques used in patients with inflammatory complications of mandibular fractures were maxillomandibular fixation and especially the use of external fixation devices. V.A. Kozlov stated that, “An attempt to use any other fixators does not provide favorable healing of the bone wound” [4]. This principle still remains valid for the treatment of traumatic osteomyelitis of long bones of the extremities. For instance, K.R. Zayzan et al. [37] suggested the use of external fixation devices in combination with systemic and local antimicrobial therapy for at least six weeks before making a decision regarding the need for fracture repair surgery.

On the contrary, P. Mehra et al [38] achieved positive results with the use of plate fixation in 44 patients with mandibular fractures complicated by inflammation. Similar results were presented by B. Alpert et al [39]. This approach is based on a relatively smaller bone mass and a smaller volume of soft tissue surrounding the fracture, which provides better conditions for effective drainage of the bone wound. Therefore, the mandibular bone damage is often not very deep. However, these studies were performed on rather small samples; hence, these results were not sufficient to recommend their wide implementation in clinical practice. Further larger-scale studies are needed, which served as the basis for our research.

V.V. Afanasiev [13] believed that the use of plate fixation is preferable for patients with traumatic osteomyelitis of the mandible compared to external fixators. The author advocated the use of plate fixation immediately after removing the sequesters, 3-

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6 weeks after the injury. However, in this case, the treatment period becomes too long, which would inevitably be associated with significant financial costs. In our opinion, there is no need to wait for the formation of sequesters, since unstable fixation of bone fragments is the leading risk factor for progressive inflammation of the bone tissue. Even in cases where such sequesters are visible on radiographs, there may be other bone lesions in adjacent areas.

On the other hand, a new generation of external fixators can significantly improve the stability of mandibular bone fixation. These include devices based on the paired insertion of threaded feathered pins passing through both compact layers of the lower jaw at an angle to each other [40]. In other devices, bicortical Schanz screws connected in an arc are used as fixing elements [42]. In this regard, many authors believed that external fixation technologies provide better clinical results, compared with plate fixation in patients with inflammatory complications [42, 43].

However, large external fixators create great inconvenience for patients and are associated with scarring; but most importantly, as mentioned above, they are still inferior to internal fixation devices in terms of the stability of fixation of bone fragments [31]. Therefore, this may not be sufficient to provide uncomplicated bone regeneration. To illustrate this assertion, we present the following observation.

Patient Sh., male, aged 19 years, a resident of Murmansk city, was in a car accident about half a year earlier. The patient had severe combined maxillofacial injury that included fractures of the maxilla and zygomatico-orbital complex, as well as bilateral fractures of the left angle and body of the right lower jaw at the level of 43, 42 with displacement of bone fragments. Splinting of the maxillofacial region was performed at a local hospital. In connection with the manifestations of meningitis, surgical interventions were not performed, only antimicrobial therapy was used. Subsequently, the patient developed signs of inflammation in the region of the mandibular fracture line. In another medical institution, an attempt was made to reposition mandibular fractures using modern extraoral pinning techniques. However, due to the presence of pronounced adhesions, this attempt failed, despite a significant load applied to the fixator, which even led to deformation of the pin. As a result, there were signs of a post-traumatic facial deformity associated with impaired healing of the bilateral mandibular fracture and an open bite.

The patient was transferred to our clinic, where the fixator was removed and revision surgery was performed on both sides with excision and removal of the scar tissue. We had to remove a bone fragment ingrown into the scar tissue, which was located between the main fragments of the mandibular bone. Bone fixation was performed using a reconstructive plate on the left and two miniplates on the right (*Figures* 8-10). The shape of the mandibular bone was restored, and the postoperative period was uneventful.

Given the low efficiency of systemic antimicrobial therapy due to impaired microcirculation in the injured area, we used preparations that provided a continuous supply of antimicrobial component to the implantation area in some patients. Another active component of these preparations was nanocrystalline hydroxyapatite, which had an indirect osteoinductive effect [44]. We chose to use this material because of its inorganic structure that prevented it from being a breeding ground for microorganisms. The use of these compositions in our patient cohort helped reducing inflammatory manifestations and providing progressive bone repair clearly seen on radiographs.

As follows from the data presented in *Tables* 3 and 4, the treatment method was successful, including in cases where suppurative processes in soft tissues preceded osteosynthesis operations. The frequencies of satisfactory and unsatisfactory outcomes in patients of Group A were slightly higher vs. Group B, as was the duration of exudative phenomena in the postoperative period, but these differences were not statistically significant. This finding implied the effectiveness of treatment in both cases.

Thus, this paper presents for the first time the experience of using an integrated approach in the surgical treatment of patients with inflammatory complications of mandibular fractures, which includes the simultaneous provision of stable fixation of bone fragments, directed antibacterial impact on the microflora of the pathological focus, and replacement of osteoplastic defect. According to the analyzed literature data, the conducted study is the largest in terms of the number of patients and performed surgical interventions, which allows us stating the creation of a sufficient evidence base.

Overall, the results showed that osteosynthesis technology with bone plates demonstrated high effectiveness in the treatment of patients with inflammatory complications of mandibular fractures, with strict adherence to the requirements of the surgical algorithm. The benefits of using plate-and-screw fixation of mandibular fractures far outweigh the potential risks of placement directly at the site of inflammation. The technique allows reducing the duration of treatment and avoiding the need for repeated hospitalizations.

Conclusion

Internal fixation is an effective method of surgical treatment of infected mandibular fractures in combination with a simultaneous directed impact on the microflora of the pathological focus and osteoplastic replacement of resulting bone defects. The use of this technique makes it possible to achieve stable fixation of bone fragments, which is a decisive factor for the healing of bone wounds. Despite the certain risk associated with the placement of metal structures in the focus of inflammation, the actual probability of further progression of inflammatory manifestations does not exceed 2.4%.

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Conflict of Interest

None declared by the authors.

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