Article

Analysis of Risk Factors and Preventive Measures for Perioperative Incision Infection in Patients Receiving Rigid Internal Fixation of Maxillofacial Fractures

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AIM: To analyze the risk factors for perioperative incision infection in patients undergoing rigid internal fixation for maxillofacial fractures and the prevention and control measures formulated to enhance the effect of surgical treatment.
METHODS: We retrospectively analyzed the medical records of 342 maxillofacial fracture patients who received rigid internal fixation treatment at the Department of Stomatological Surgery of The First People's Hospital of Yongkang (Yongkang First People's Hospital) from May 2018 to April 2023, and divided them into the uninfected group (n = 308) and the infected group (n = 34) according to their history of perioperative incision infections. Data from the subjects on age, type of fracture trauma and length of hospitalization were collected and analyzed. Multifactorial logistic regression analysis was employed to explore the risk factors for perioperative incision infections in these patients and to develop preventive measures for these risk factors.
RESULTS: The study found that the incidence of incision infections was 9.94% (34/342) in 342 patients. Multifactorial logistic regression analysis showed that the incidence of incision infections was significantly higher in patients with comorbid diabetes mellitus versus those without comorbid diabetes mellitus (odds ratio [OR] = 9.543, 95% confidence interval [CI]: 1.818–50.095, p = 0.008); patients undergoing surgery in summer versus those in other seasons (OR = 8.483, 95% CI: 1.476–48.744, p = 0.017); and malnourished patients versus those with good nutritional status (OR = 5.163, 95% CI: 1.016–26.231, p = 0.048). In addition, the analysis also revealed that incision size was also a risk factor for incision infections during the postoperative period (OR = 2.882, 95% CI: 1.567–5.304, p = 0.001), whereas a higher preoperative albumin level was a protective factor (OR = 0.755, 95% CI: 0.639–0.891, p = 0.001).
CONCLUSIONS: A plethora of risk factors can lead to incision infection in patients with maxillofacial fracture during perioperative period. Therefore, preventive measures should be implemented in the hospitals to control these factors in order to reduce the occurrence of complications and enhance the effectiveness of surgical treatment.

Keywords: fracture fixation; maxillofacial injuries; perioperative period; infections; risk factors

Introduction

Facial fractures are collectively listed as a common cause of emergency department visits, with 400,000 visits per year being recorded in the United States alone. Trauma to the face can result in a variety of fracture patterns [1], of which maxillofacial injuries represent one of the most common injuries, commonly affecting adult males [2]. Of the major concern in modern medicine and the public health service is maxillofacial fractures, generally caused by road collisions, violence or sports injuries, which lead to soft tissue injuries to the face and mouth, dental injuries as well as craniofacial fractures [3]. Rigid internal fixation is mainly used for the treatment of maxillofacial fractures and improves the rate of treatment excellence, reduces the length of hospitalization and fracture healing time. It is also effective in restoring the patient's oral function and facial appearance. Studies have found that wound infection is the most common complication after incisional reduction and internal fixation [4], which are complex and costly to manage, with high morbidity and financial impact on the patient, and despite the use of prophylactic antibiotics, surgical site infections remain one of the most common complications in surgical cases of maxillofacial trauma [5]. The treatment of incision infections often entails additional medical interventions, such as removal of infected tissue and use of antibiotic medications, which not only increase the physiological burden on the patient, but also increase healthcare costs. At the same time, infection can also lead to delayed healing, affecting patients' functional recovery and quality of life. Therefore, actively exploring the risk factors for perioperative incision infection in patients with maxillofacial fracture and formulating targeted preventive and curative measures is of great significance to enhance the effectiveness of surgical treatment, reduce patients' pain, decrease medical costs, and promote postoperative recovery. In the present study, we analyze the risk factors affecting the perioperative occurrence of incision infection in these patients, so as to provide

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more reference for the formulation and selection of appropriate treatment regimens.

Methods

Patient Information

A total of 342 patients with maxillofacial fractures who underwent rigid internal fixation at the Department of Oral Surgery of The First People's Hospital of Yongkang (Yongkang First People's Hospital) from May 2018 to April 2023 were selected for this study, which was conducted in accordance with the Declaration of Helsinki [6], and was approved by the Ethics Committee of The First People's Hospital of Yongkang (Yongkang First People's Hospital) (Ethics No. YKSDYRMYYEC2024-LW-KS-035-01). Informed consent was obtained from the patients or their families.

Inclusion and Exclusion Criteria

Inclusion Criteria

The inclusion criteria of this study are as follows:

(1) Individuals eligible for rigid internal fixation treatment indications (such as comprehensive fracture, multiple or comminuted maxillary and mandibular fractures, obviously displaced maxillary and mandibular fractures, etc).

(2) Individuals with complete medical records (including complete basic information, such as name, sex, age; admission records, such as patient's main complaint, current medical history, past history; records of the surgical process).

(3) Individuals without serious postoperative complications, such as wound bleeding with more than 400 mL in a single event, craniocerebral injury, shock, etc.

(4) Age $>$18.

Exclusion Criteria

Patients who were pregnant or breastfeeding were excluded from this study.

Methodology

Information regarding patients' medical history was collected, along with sex, age, body mass index (BMI), education level, occupation, fracture type, anesthesia classification, length of hospital stay, comorbid diabetes mellitus, duration of surgery, size of incision, preoperative albumin level, history of smoking [7], history of alcohol consumption [8], surgery during summer, type of incision, and nutritional status. According to the Expert Consensus on the Diagnostic Criteria for Malnutrition published by the European Society of Clinical Nutrition and Metabolism [9], malnutrition is diagnosed when a patient with a positive screening for nutritional risk meets any one of the following four criteria: (a) BMI $<$18.5 kg/m^2; (b) Weight loss: involuntary weight loss $>$10%, 3-month involuntary weight loss $>$5%, accompanied by a decrease in BMI (age $<$70 years, BMI $<$20 kg/m^2 or age $\geq$70 years, BMI $<$22 kg/m^2); (c) Weight loss: voluntary weight loss $>$10%, 3-month involuntary weight loss $>$5%, accompanied by a decrease in the fat-free mass index (FFMI); (d) Weight loss: voluntary weight loss $>$10%, 3-month involuntary weight loss $>$5%, accompanied by a decrease in the defatted FFMI (FFMI loss: $<$15 kg/m^2 for women and $<$17 kg/m^2 for men), and the presence of oral diseases (including: dental caries, pulpitis, apical periodontitis, etc.) to analyze the influencing factors that lead to incision infections in patients [10].

Statistical Methods

The collected data were analyzed and processed using the Statistical Product and Service Solutions (SPSS) software (version 26.0, International Business Machines Corporation, Armonk, NY, USA). Firstly, the Shapiro-Wilk test was used to test the normal distribution of continuous variables, and for data that did not meet the normal distribution, M (P_{25}, P_{75}) was used as descriptive statistics, and the comparisons between groups were performed using the Wilcoxon rank-sum test; and for the categorical variables, the number of cases (percent) was used for representation, and between-group comparisons were performed using Pearson's chi-square test or continuity-corrected chi-square (Pearson's chi-square was used when the total sample size was $\geq$40 and the theoretical frequency in each cell was $\geq$5; continuity-corrected chi-square was used when the total sample size was $\geq$40 and the theoretical frequency in each cell was $1 \leq T < 5$). Logistic regression analysis was used to explore the risk factors affecting postoperative incision infection in patients with maxillofacial fractures treated with rigid internal fixation, and the difference was considered statistically significant when $p < 0.05$.

Results

Patient Inclusion Process

The study process is detailed in Fig. 1.

Univariate Analysis of Incision Infection in Patients with Maxillofacial Fractures Undergoing Rigid Internal Fixation

Of the 342 patients with maxillofacial fractures, 34 had postoperative incision infections, and the incidence of incision infection was 9.94%. There were no significant differences between the two groups in terms of sex, age, BMI, education level, occupation, anesthesia grading, duration of surgery, length of hospital stay, history of alcohol consumption, and type of incision ($p > 0.05$), while there were significant differences in terms of site of injury, type of fracture trauma, comorbidity with diabetes mellitus, size of the incision, preoperative albumin level, smoking history, surgery during summer, nutritional status, and presence of oral disease ($p < 0.05$), as demonstrated in detail in Table 1.

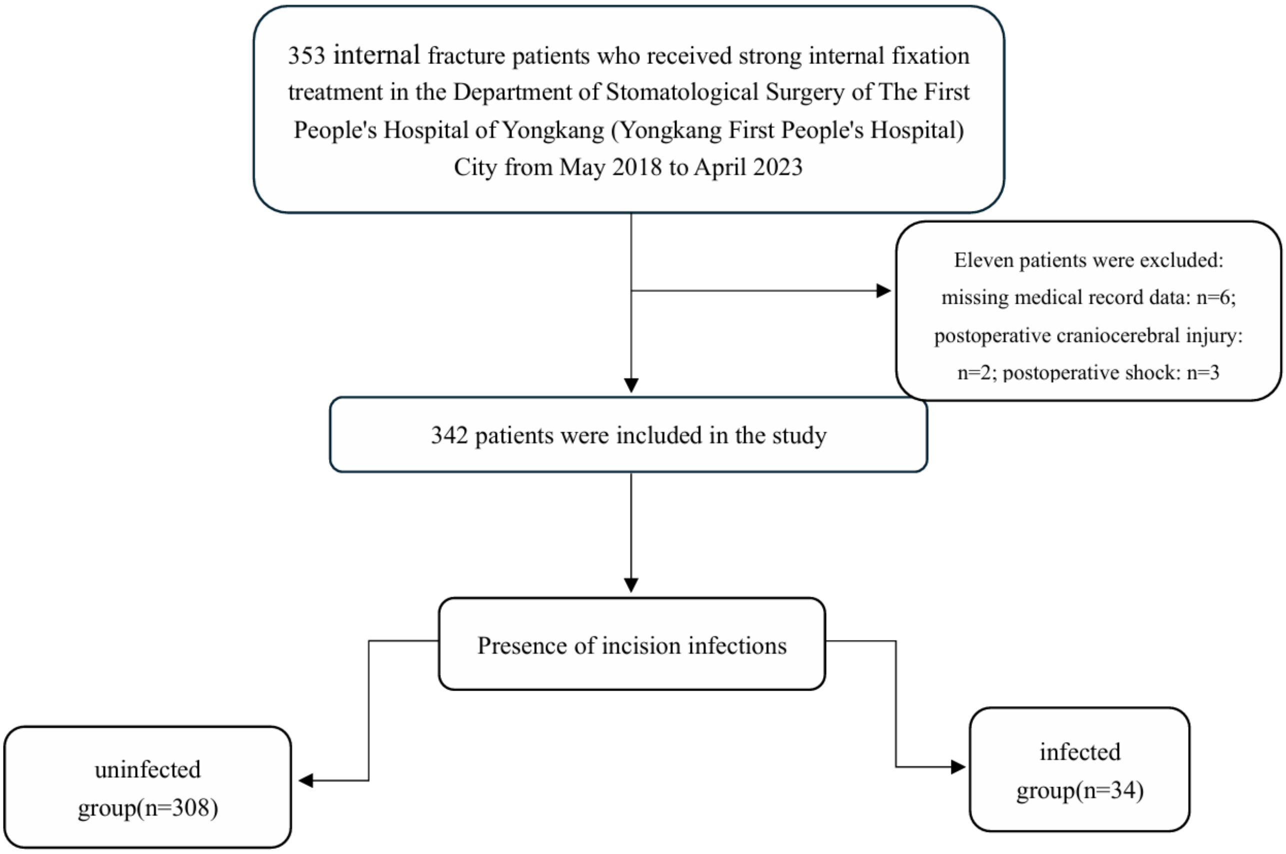

Fig. 1. Flow of the study.

Multivariate Logistic Regression Analysis of Perioperative Incision Infection in Patients with Maxillofacial Fractures

Multifactorial logistic regression analysis was performed with the occurrence of incision infection as the dependent variable, and the factors with statistically significant differences in the univariate analysis as the independent variables; the variable assignment in the analysis is detailed in Table 2. Multivariate logistic regression analysis showed that being comorbid with diabetes greatly increased the risk of incision infections in patients with maxillofacial fractures (odds ratio [OR] = 9.543, 95% confidence interval [CI]: 1.818–50.095, p = 0.008), thus requiring specific interventions for this subgroup of patients. The risk of incision infection was significantly higher during summer (OR = 8.483, 95% CI: 1.476–48.744, p = 0.017), suggesting that environmental factors play a crucial role and necessitating heightened infection control during the summer months. Malnutrition increases the risk of incision infections (OR = 5.163, 95% CI: 1.016–26.231, p = 0.048), so nutritional screening should be implemented in patients preoperatively and necessary interventions should be formulated. Longer incision length (OR = 2.882, 95% CI: 1.567–5.304, p = 0.001) was also found to cause a high prevalence of incision infections, indicating the need to consider incision size given the patient's own situation and develop the necessary preventive measures against infections. Additionally, a higher albumin level in the preoperative period was found to be a protective factor (OR = 0.755, 95% CI: 0.639–0.891, p = 0.001). These data are demonstrated in Table 3.

Discussion

Maxillofacial fractures can severely affect a patient's diet, leading to weight loss, and the trauma can affect the masticatory muscles and facial bones, resulting in a bite force reduction [11]. Maxillofacial injuries, due to their varied etiology, are often considered a component of polytrauma and form an important part of trauma [12]. It has been found that incisional repositioning and internal fixation using plates and screws enhances the stability and correction of anatomical structures and improves the recovery of occlusal force and occlusal function [13]. It has also been suggested that incisional reduction and internal fixation of condylar fractures provides satisfactory clinical and early functional outcomes, prompting its wide adoption for maxillofacial fracture treatment [14]. However, surgical site infection is a complication of oral and maxillofacial surgery that can further lead to serious complications and mortality, and severe trauma also increases the overall incidence of complications and infection [15]. A large retrospective study conducted in China found that among 1558 patients with maxillofacial fractures who underwent surgical treatment, 27 cases developed postoperative infections, with an incidence rate of

Table 1. Univariate analysis of incision infection in patients after undergoing rigid internal fixation.

Variable	Infected group (*n* = 34)	Uninfected group (*n* = 308)	Statistical value	*p*-value
Sex			0.046	0.831
Male	20 (58.82)	187 (60.71)		
Females	14 (41.18)	121 (39.29)		
Age (years)	36.50 (32.00, 45.00)	38.00 (29.00, 45.75)	–0.015	0.988
BMI (kg/m^2)	23.60 (21.48, 25.60)	22.70 (21.10, 24.70)	–1.557	0.120
Education level			2.318	0.314
University and above	6 (17.65)	29 (9.42)		
High school or secondary school	18 (52.94)	186 (60.39)		
Junior high school and below	10 (29.41)	93 (30.19)		
Occupation			0.366	0.947
Peasant	15 (44.12)	129 (41.88)		
Clerical staff	2 (5.88)	26 (8.44)		
Worker	12 (35.29)	113 (36.69)		
Hiring out	5 (14.71)	40 (12.99)		
Site of injury			7.930	0.047
Maxilla	9 (26.47)	77 (25.00)		
Mandible	15 (44.12)	82 (26.62)		
Zygomatic bone	6 (17.65)	124 (40.26)		
Zygomatic arch	4 (11.76)	25 (8.12)		
Types of fracture trauma			10.624	0.001
Closed injury	15 (44.12)	220 (71.43)		
Open injury	19 (55.88)	88 (28.57)		
Comorbid diabetes			48.498	$<$0.001
Be	18 (52.94)	27 (8.77)		
Clogged	16 (47.06)	281 (91.23)		
Classification of anesthesia			0.890	0.641
Class I	17 (50.00)	176 (57.14)		
Class II	14 (41.18)	102 (33.12)		
Class III	3 (8.82)	30 (9.74)		
Length of hospital stay (d)	6.00 (5.00, 7.00)	6.00 (5.00, 8.00)	–1.328	0.184
Duration of surgery (min)	70.00 (64.00, 76.25)	68.00 (56.00, 76.00)	–1.881	0.060
Incision size (cm)	10.00 (8.00, 11.00)	6.00 (4.00, 7.00)	–23.217	$<$0.001
Preoperative albumin level (g/L)	32.00 (26.00, 36.00)	39.00 (33.00, 44.00)	–30.651	$<$0.001
Smoking history			6.203	0.013
Smoker	12 (35.29)	54 (17.53)		
Non-smoker	22 (64.71)	254 (82.47)		
Drinking history			0.306	0.580
Remain	13 (38.24)	133 (43.18)		
Non-existent	21 (61.76)	175 (56.82)		
Surgery during summer			15.857	$<$0.001
Be	17 (50.00)	61 (19.81)		
Clogged	17 (50.00)	247 (80.19)		
Type of incision			5.541	0.236
Mandibular vestibular groove incision	7 (20.59)	68 (22.08)		
Submarginal incision	11 (32.35)	59 (19.16)		
Anterior incision of the ear screen	9 (26.47)	65 (21.10)		
Submandibular incision	5 (14.71)	86 (27.92)		
The rest	2 (5.88)	30 (9.74)		
Nutritional status			27.124	$<$0.001
Favorable	14 (41.18)	249 (80.84)		
Undesirable	20 (58.82)	59 (19.16)		
Oral diseases			27.556	$<$0.001
Present	19 (55.88)	53 (17.21)		
Not present	15 (44.12)	255 (82.79)		

Data are expressed as *n* (%) or M (P_{25}, P_{75}). BMI, body mass index.

Table 2. Variables and assignments.

Variable	Assignment
Incision infection (Y)	Occurrence = 1, No occurrence = 0
Site of injury	Maxillary fracture = 1, Mandibular fracture = 2, Zygomatic fracture = 3, Zygomatic arch fracture = 4
Types of fracture trauma	Closed injury = 1, Open injury = 0
Comorbid diabetes	Yes = 1, No = 0
Smoking history	Yes = 1, No = 0
Surgery during summer	Yes = 1, No = 0
Nutritional status	Undesirable = 1, Favorable = 0
Oral diseases	Present = 1, Not present = 0
Incision size	Substituted with the original value
Preoperative albumin level	Substituted with the original value

Y is the dependent variable.

Table 3. Multivariate logistic regression analysis of perioperative incision infection in patients receiving rigid internal fixation for maxillofacial fractures.

Variables	Beta value	Standard error	Wald	Significance	OR	95% CI	
Site of injury			5.393	0.145			
Fracture of the mandible	1.767	1.062	2.768	0.096	5.854	0.730	46.939
Zygomatic bone fracture	0.164	1.090	0.023	0.881	1.178	0.139	9.973
Zygomatic arch fracture	–1.085	1.526	0.506	0.477	0.338	0.017	6.722
Types of fracture trauma	–1.252	0.804	2.428	0.119	0.286	0.059	1.381
Comorbid diabetes	2.256	0.846	7.110	0.008	9.543	1.818	50.095
Smoking history	1.395	0.791	3.111	0.078	4.035	0.856	19.009
Surgery during summer	2.138	0.892	5.744	0.017	8.483	1.476	48.744
Nutritional status	1.641	0.829	3.917	0.048	5.163	1.016	26.231
Oral diseases	1.465	0.814	3.240	0.072	4.327	0.878	21.325
Incision size	1.059	0.311	11.579	0.001	2.882	1.567	5.304
Preoperative albumin level	–0.281	0.085	11.013	0.001	0.755	0.639	0.891

OR, odds ratio; CI, confidence interval.

about 1.73% [16], which is lower than the incidence rate of 9.94% in the present study. The difference in the incidence rate between the two studies may be attributed to the following: (1) Most of the patients in the former study were adolescents and young adults, and 44.4% of the patients were under 30 years of age, whereas the patients included in the present study were mostly between 30 and 50 years of age. The age difference accounts for the optimal immune system function and metabolism to expel pathogens and viruses at younger age, which greatly reduces the risk of postoperative infection. (2) The samples selected for this study were recruited in the domestic famous dental hospitals, where excellent surgical techniques and strict perioperative interventions are applied and implemented, allowing for a more effective control of the incidence of postoperative infections. Superior surgical techniques and strict perioperative interventions are the basis and key to reducing the incidence of postoperative infections. Foreign scholars have also found that in an eight-year epidemiologic study of a county hospital in western Norway from 2002 to 2009, the incidence of postoperative infections in 139 maxillofacial fracture patients accounted for 8.6% [17], which is similar to the incidence of infection in this study.

Based on the fact that incision infection after rigid internal fixation can seriously affect the recovery of maxillofacial fracture patients, we aimed to collect and analyze medical records of these patients and use logistic regression to analyze the risk factors of postoperative incision infection, which serve as the basis for better prevention of this complication.

Ultimately, our study found that comorbid diabetes, malnutrition, surgery during summer, incision size and preoperative albumin level were influential factors for postoperative incisional infections in these patients, which were analyzed for the following reasons: (1) A study reportedthat patients with insulin-dependent diabetes mellitus appear to be at higher risk for surgical site infections and wound complications compared to non-diabetic patients [18]. The hyperglycemic state in diabetic patients leads to suppression of the function of immune cells (e.g., macrophages, neutrophils, and lymphocytes). These immune cells are able to effectively clear infectious agents under normal conditions, but their activity and potency are reduced in a hyperglycemic milieu. When the incision site is overwhelmed with pathogenic bacteria, the declining number and function of immune cells will pose hindrances for the effective bacterial elimination, thus increasing the risk of incision infection. Furthermore, when the incision of a diabetic patient is infected, the infection will further aggravate the condition of diabetes. Infection triggers an inflammatory response in the body, causing the body to be in a state of stress, which in turn prompts an increased secretion of some of the body's glucagon hormones (e.g., epinephrine, glucocorticoids, etc.). These hormones will antagonize the action of insulin, making blood sugar rise further and blood sugar difficult to control. In turn, hyperglycemia will affect wound healing, creating a vicious cycle that further increases the risk and severity of incision infection [19]. (2) Malnutrition can affect incision healing, thereby increasing the incidence of surgical site infections in patients [20]. Malnutrition may affect local fibroblast proliferation and collagen secretion, while a decrease in lymphocyte counts due to malnutrition may cause damage to the immune system, reducing the ability to fight infection [21]. It may also lead to poor hemostasis or hematoma formation during surgery, which may reduce the local blood supply to the incision area, leading to local ischemia and inflammation, thus increasing the risk of infection [22]. (3) A systematic review showed that the risk of surgical site infection increases after surgery performed in summer [23]. After studying the seasonal effects on infection rates following various body contouring surgeries, Duscher *et al*. [24] found a significant increase in infection rates during the warmer seasons and a direct correlation between high temperatures and the risk of postoperative infection. We can therefore speculate that this may be related to the higher temperatures and humidity during the summer months, and environmental conditions that are favorable for bacterial growth and reproduction. In addition, high temperatures in summer may lead to changes in the skin and wound healing environment, thus increasing the risk of infection. Also, the frequent use of air conditioning in hospitals during the summer may lead to an increased microbial load in the indoor air, thus increasing the risk of postoperative infections. (4) An increase in the incision length implies a greater extent of surgical trauma, which may lead to more tissue damage and bleeding, thus increasing the risk of infection [25]. Longer incisions may require more sutures involving more complex suturing techniques, which may increase the chances of bacterial contamination during surgery, thus raising the risk of infection [26]. (5) Serum albumin is the main source of plasma colloid osmolality and is essential for maintaining fluid balance and blood volume both inside and outside the blood vessels [27]. Hypoalbuminemia leads to a decrease in plasma colloid osmotic pressure, which affects intravascular fluid balance and increases edema and inflammatory response. In addition, albumin has an immunomodulatory function, and hypoalbuminemia may weaken the body's immune function, predisposing the patients to infection. Hypoproteinemia exacerbates the inflammatory response, leading to increased local inflammation and affecting incision healing [28].

For the risk factors screened in this study, the relevant preventive measures are as follows: keep the patient's respiratory tract smooth, give the patient a light liquid diet, avoid spicy and stimulating food, do not eat hard food, limit the face to a large movement, and do not squeeze and collide with the affected area, so as to avoid the displacement of the fracture block. Preoperative nutritional assessment should be conducted for patients, especially those suffering malnutrition. Essential reply the surgical incision should be scientifically designed before surgery; the intraoperative procedures should be standardized; and the wound in the oral cavity should be carefully sutured under the strictest standards. The wound should be cleaned regularly and sterile materials should be used when changing the dressing in accordance with doctor's instructions. The wound should be prevented from moisture and thus, breathable sterile gauze is utilized to cover the wound to ensure dryness. For diabetic patients undergoing oral surgery treatment, preoperative antibiotics are recommended to better promote wound healing and reduce the risk of infection [29]. After surgery, oral hygiene maintenance of the surgical area needs to be strengthened, and antimicrobial drugs should be used when necessary. Importantly, eating, mouth rinsing and gargling must be done gently after operation to avoid exacerbation of soft tissue wounds [30]. Focused incision management based on the patient's condition, the use of gauze pads for protection, reduction of foreign body residual irritation, and prompt use of antibiotics and other medications can be effective in reducing the incidence of postoperative incision infections.

Several limitations of the present study merit our attention. The retrospective nature of the present study limits the control of variables and the determination of causality. In addition, analyzing medical records stemming from one hospital only in the present study may result in selection bias. The original intention of this study was to delve deeper into the intrinsic mechanisms that cause incisional infections in patients undergoing this type of surgery by constructing a clinical prediction model. However, some challenges encountered during sample collection led to a limited sample size; only 34 cases with incisional infections were collected. However, this number is far below the ideal sample size required to conduct a robust modeling analysis, and due to the limited sample size, a model with statistical significance and good predictive performance was not successfully constructed. Specifically, the insufficient sample size leads to unstable model parameter estimates, making the model unsatisfactory on the training set, let alone internal and external validation on an independent validation set. Thus, a model constructed with a small sample size would adversely undermine its reliability and ability in generalizing the results, which affects the in-depth understanding and interpretation of the results. Future studies need to integrate data from larger samples to ensure that models with statistical significance and practical applications can be constructed. Although failed to achieve the expected modeling analysis and validation, the study still provides some reference value regarding the occurrence of perioperative incision infections in patients having undergone this type of oral surgery. In future studies, we will establish cooperative relationships with other medical institutions or research centers to conduct multicenter and large-sample studies, thereby improving the reliability and generalizability of the results, and conduct prospective studies to further validate and supplement the results of retrospective studies so as to provide a more in-depth and comprehensive understanding to advance the field of oral surgery.

Conclusions

A myriad of risk factors is accountable for the incidence of postoperative incision infections in patients receiving rigid internal fixation of maxillofacial fractures. To mitigate these infections, these risk factors should be controlled at the clinical settings and during the perioperative period to prevent the occurrence of incision infection so as to minimize the impact of complications on the patients and improve the surgical effectiveness.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

FXX and FW designed the research study. FXX and FW performed the research. FXX and FW analyzed the data. FXX drafted the manuscript. Both authors contributed to important editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee of The First People's Hospital of Yongkang (Yongkang First People's Hospital), (Ethics No. YKSDYRMYYEC2024-LW-KS-035-01). Informed consent was obtained from the patients or their families.

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Conflict of Interest

The authors declare no conflict of interest.

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