



Factors associated with treatment outcomes of patients hospitalized with severe maxillofacial infections at a tertiary center

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Objectives: The purpose of this retrospective study was to evaluate the variables associated with length of stay (LOS), hospital costs, intensive care unit (ICU) use, and treatment outcomes in patients hospitalized for maxillofacial infections at a tertiary medical center in South Korea.

Materials and Methods: A retrospective chart review was conducted for patients admitted for treatment of maxillofacial infections at Dankook University Hospital from January 1, 2011 through September 30, 2020. A total of 390 patient charts were reviewed and included in the final statistical analyses.

Results: Average LOS and hospital bill per patient of this study was 11.47 days, and ₩4,710,017.25 (\$4,216.67), respectively. Of the 390 subjects, 97.3% were discharged routinely following complete recovery, 1.0% expired following treatment, and 0.8% were transferred to another hospital. In multivariate linear regression analyses to determine variables associated with LOS, admission year, infection side, Flynn score, deep neck infection, cardiovascular disease, admission C-reactive protein (CRP) and glucose levels, number and length of surgical interventions, tracheostomy, time elapsed from admission to first surgery, and length of ICU stay accounted for 85.8% of the variation. With regard to the total hospital bill, significantly associated variables were age, type of insurance, Flynn score, number of comorbidities, admission CRP, white blood cell, and glucose levels, admission temperature, peak temperature, surgical intervention, the length, type, and location of surgery, tracheostomy, time elapsed from admission to first surgery, and length of ICU use, which accounted for 90.4% of the variation. Age and ICU use were the only variables significantly associated with unfavorable discharge outcomes in multivariate logistic regression analysis.

Conclusion: For successful and cost-effective management of maxillofacial infections, clinicians to be vigilant about the decision to admit patients with maxillofacial infections, perform appropriate surgery at an adequate time, and admit them to the ICU.

Key words: Abscess, Bacterial infections, Retropharyngeal abscess, Maxillofacial surgery, Antibiotics

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I. Introduction

Maxillofacial abscess or cellulitis is an infection of the soft tissues of the face and neck area that arises from odontogenic or nonodontogenic causes¹. During the initial stage, maxillofacial infections are usually mild and prevention and treatment are often straightforward and relatively inexpensive, consisting of appropriate surgical procedures and antibiotics

in an outpatient clinic setting. However, infections that spread beyond the initial border can lead to life-threatening maxillofacial complications such as necrotizing fasciitis, cavernous sinus thrombosis, airway obstruction, mediastinitis, and sepsis, and therefore require hospital admission^{1,2}. This can result in delayed recovery, prolonged hospital stay, intensive care unit (ICU) admission, increased risk of mortality, and a substantial increase in the overall costs of treatment^{2,3}. Severe maxillofacial infections can therefore be a significant economic burden to both health care facilities and patients.

However, there is a paucity of literature examining the financial aspects of hospitalization of patients with head and neck infections, and the parameters of these important cost variables are poorly understood. The few studies regarding hospital costs that have been performed have been limited to Western populations, but such results are likely biased due to regional differences in the epidemiology of maxillofacial

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infections and health insurance systems¹⁻¹⁰. In this era in which cutting budgets is considered important, it is crucial that surgeons and hospitals strive to minimize costs while still maintaining the highest level of patient care. Objective data regarding variables associated with increased hospitalization costs are therefore required. An epidemiologic study to identify the distinct characteristics of severe maxillofacial infections in Asian countries would help improve overall outcomes and reduce overall health care costs.

The objective of this retrospective study was to describe the demographic characteristics, treatment outcomes, and hospital costs of patients hospitalized in a tertiary center in South Korea for the treatment of severe maxillofacial infections, and to identify the associations between these treatment outcomes and diverse social, patient health, and treatment-related variables.

II. Materials and Methods

1. Study design

After obtaining approval from the Institutional Review Board of Dankook Dental University Hospital (No. DKUDH IRB 2020-09-007), records of patients admitted to the Oral and Maxillofacial Surgery (OMFS) Department, Dankook University Hospital, for the treatment of maxillofacial infections from January 2011 through September 2020 were reviewed. The billing department performed a computer search of billing data attached to the electronic medical record numbers of patients with the relevant diagnostic codes from the seventh revision of the Korea Informative Classification of Diseases (KCD7). KCD7 codes used to identify relevant patients were K04.6 (periapical abscess with sinus), K04.7 (periapical abscess without sinus), K05.21 (periodontal abscess of gingival origin with sinus), K11.3 (abscess of the salivary gland), K12.2 (cellulitis and abscess of the mouth), K14.0 (abscess and ulceration of the tongue), J36 (peritonsillar abscess), J39.0 (retropharyngeal and parapharyngeal abscess), and J39.1 (other abscess of the pharynx). Retrieved positive records were then cross-checked with the relevant codes to ensure that admissions were related to a maxillofacial infection. An additional, complete manual review of patient admission data was also performed to identify additional records not identified by the electronic search process. Exclusion criteria for this study were patients treated only in an outpatient setting, incomplete data acquisition from electronic charts, patients not yet discharged from the hos-

pital, patients who were initially admitted for reasons other than maxillofacial infections but who developed infection secondary to other maxillofacial surgeries, and patients for whom the OMFS service was not consulted. To focus on the characteristics and outcomes of more severe, potentially fatal infections, the current study was limited to cases that required hospital admission for treatment. To ensure that the exclusion criteria were applied and that recording of the relevant data was accurate, each chart was reviewed twice by two separate reviewers. At the reviewing stage, the reviewers were blinded to the hospital bills of each subject to eliminate the possibility of bias in collecting data. Names of the subjects were not revealed to protect personal information.

2. Independent variables

All variables extracted from patient records were recorded and organized on an electronic Microsoft Excel 2021 (Microsoft, Redmond, WA, USA) spreadsheet. Independent variables examined in the present study comprised a heterogeneous set of demographic, individual health status, hospital course, infection, and treatment-related variables.

Demographic variables were age, sex, ethnicity (Korean or not Korean), insurance coverage status (National Health Insurance [NHI], medical aid, or uninsured), and admission year. Age, sex, and ethnicity were determined based upon information in patients' medical records. Information regarding insurance status was provided by the billing department. Admission year was determined based on admission and discharge dates. When the patient was admitted at the end of one year and discharged the next year, the admission year was considered the year with the longer length of stay (LOS).

Variables related to an individual's health status were the presence of any kind of comorbidity, the number of comorbidities, smoking, and the burden of each type of comorbid condition. All these variables were noted as written in the nursing admission assessment form. To assess the burden of comorbid conditions such as diabetes, endocrine disease, nephrotic disease, hepatic disease, cardiovascular disease, and psychological disease, each condition was tested bivariately and only those associated significantly with outcomes were included in the final statistical analysis.

Hospital course-related variables were route of admission (via outpatient clinic or emergency room [ER]), hospital arrival time (morning [00:00 to 08:00], day [08:00 to 16:00], or evening [16:00 to 24:00]), and time elapsed from symptom onset to admission, from admission to first surgery, and from

symptom onset to first surgery (in days). Route of admission and hospital arrival time were determined from information provided by the billing department. Date of symptom onset was recorded as described by the patients at the time of the first ER or outpatient clinic visit. Date of the first surgery was determined from the procedure and surgery notes.

Infection-related variables included the infection's etiology (odontogenic or non-odontogenic), number of infected anatomical spaces, infected location, presence of deep neck space infection, presence of necrotizing fasciitis, Flynn score, C-reactive protein (CRP) level, white blood cell (WBC) count, glucose level upon admission, body temperature upon admission, and peak body temperature during hospital stay. Information regarding the infection's etiology and spaces involved was determined by concomitant review of discharge summaries and enhanced neck computed tomography scans. An odontogenic infection severity score was assigned to each infection based on a scoring system suggested in a previous study by Flynn et al.⁴, in which each infected fascial space is scored on the basis of its proximity to the airway, other vital structures, and likelihood of preventing airway access; the total score is the aggregate of these values. Thus the vestibular, subperiosteal, infraorbital, canine, and buccal spaces were assigned a score of 1, the submandibular, submental, sublingual, and masticatory spaces a score of 2, and the lateral pharyngeal, retropharyngeal, pretracheal, mediastinal, and intracranial spaces a score of 3. Body temperatures were determined through review of the patient's daily clinical examination form, and were categorized as 37.5°C or more or less than 37.5°C.

Treatment-related variables included antibiotic regimen, performance of incision and drainage, tracheostomy, any type of surgical intervention after admission, general anesthesia (GA), additional surgery, additional operating room (OR) uses, total number of OR visits, surgeries, type and location of surgeries received, ICU use, and length of ICU stay. Antibiotic regimen was categorized based upon the most commonly utilized combinations of antibiotics during the reviewed period, and was clarified by reviewing the daily prescription data. All information regarding surgical interventions and GA was obtained by comprehensive review of the information recorded on emergency department records, daily procedure notes, daily inpatient notes, surgery notes, anesthesia notes, and discharge summaries. Among surgery-related variables, length of surgery was calculated as the difference between the recorded 'procedure start' and 'procedure end' times on the anesthesia note. Information regarding ICU

stay was provided by the billing department.

3. Outcome variables

Primary outcome variables of interest were total hospital charges, LOS in hospital (in days), mean hospital bill per one hospital admission day, use of ICU services, and disposition status (routine discharge following complete recovery, transfer to another hospital, discharge against medical advice, death). Total hospital charges were determined as the sum of the final amount billed to the patient and the bill covered by the NHI service in Korean Won, which was obtained from data provided by the billing department. LOS indicates the total number of days that the patient stayed in the hospital since admission. Mean hospital bill per one admission day was calculated as the total hospital bill divided by the total LOS in days. Disposition status was copied from the discharge records.

4. Statistical analysis

All retrieved data were compiled, matched with the outcome data, and imported into IBM SPSS Statistics (ver. 27.0; IBM, Armonk, NY, USA) for statistical analyses. Descriptive statistics were computed for all variables. Because data regarding hospital charges were highly skewed and not normally distributed, the billing data was log-transformed to adjust for violation of the normality assumption. For preliminary univariable analysis, data were analyzed using the *t*-test, Mann–Whitney test, analysis of variance, Kruskal–Wallis test, Pearson's correlation analysis, χ^2 test, and Fisher's exact test as appropriate for the bivariate analysis performed. A *P*-value less than 0.05 was considered to be statistically significant. All variables with statistically significant associations with the dependent variables (*P*<0.05) from the initial univariable analysis were used to formulate a preliminary multiple linear regression model for the continuous dependent variables, and a preliminary multiple logistic regression model for the binary dependent variables. The final multiple regression models included all variables from the preliminary model with *P*-values lower than 0.05. In all regression models, adjustments were made for the clustering of outcomes. All statistical analyses were two-sided.

III. Results

1. Patient data

A total of 401 patients were identified via the initial electronic chart review. Of these patients, 390 (205 male, 185 female) met the inclusion criteria and were thus included in the final analysis. The remaining 11 patients were excluded from the study because only incomplete data regarding the type or location of surgery could be acquired from the electronic charts (n=6), the patients were initially admitted for reasons other than maxillofacial infection (n=4), or were not yet discharged (n=1).

2. Demographics and insurance status

Demographic traits of the reviewed subjects are summarized in Table 1. In total, 52.6% of subjects were male and 47.4% were female. Mean age at presentation was 54.69 ± 20.83 years (range, 4-90 years). Only 2.1% of subjects were not Korean. Of the patients, 93.1% were insured by the NHI, 5.9% by medical aid, and the remaining 1.0% were not insured. The number of patients admitted each year did not differ significantly.

3. Health status

Data related to the health status of the patients included in this study are summarized in Table 1. Among the population studied, 59.0% of patients had multiple comorbidities. Mean number of comorbid conditions present per patient was 1.21 ± 1.33 (range, 0-6). One hundred thirty-nine patients (35.6%) were cigarette smokers.

4. Hospital course

Descriptive statistics pertaining specifically to subjects' hospital course are depicted in Table 1. Most patients were admitted via the ER (83.3%), and 67.9% of the initial visits were made during the daytime. Mean number of days that elapsed from symptomatic onset to admission was 7.23 ± 7.97 days (range, 0-60 days), to first surgery was 7.89 ± 7.55 days (range, 0-50 days), and mean number of days from admission to first surgery was 0.78 ± 1.79 days (range, 0-12 days).

5. Etiology, location, and severity of infection

Relevant information regarding the characteristics of the infections are illustrated in Table 1. Average number of infected anatomical spaces per patient was 2.16 ± 1.47 (range, 1-9), mean Flynn score was 4.13 ± 3.13 (range, 1-19), and there were infections in both sides of the face and neck in 26 cases (6.7%). Deep neck involvement was noted in 51 patients (13.1%), while the presence of necrotizing fasciitis was confirmed in 13 patients (3.3%). Only 11 cases (2.8%) were due to non-odontogenic causes. Mean CRP, WBC, and serum glucose levels upon admission were 13.12 mg/dL, $13.91 \times 10^3/\mu\text{L}$, 140.25 mg/dL, respectively. While only 64 cases (16.4%) presented to the hospital with a body temperature higher than 37.5°C , 149 patients (38.2%) developed fever during the hospital stay.

6. Treatment

Descriptive data regarding treatment-related variables are shown in Table 1. Most patients underwent incision and drainage (82.3%) and surgery after admission (66.9%) in the OR (40.0%), but did not require operation under GA (62.1%), additional surgery (81.8%), additional GA (95.6%), tracheostomy (96.7%), or any other surgical interventions other than incision and drainage (67.2%). Of the 390 patients, 62 patients (15.9%) did not receive any kind of surgical treatment at all but were treated conservatively with intravenous antibiotics. The most common antibiotic regimen used to treat the majority of the reviewed infections (73.8%) was concomitant use of amoxicillin-sulbactam or ceftriaxone with clindamycin. Only 46 cases (11.8%) required a stay in the ICU for more than one day, and the average LOS in the ICU was 1.12 ± 6.09 days (range, 0-94 days).

7. Total hospital bill, LOS, and treatment outcomes

Mean hospital bill was ₩4,710,017.25 (4,216.67 USD), and mean LOS was 11.47 ± 10.62 days (range, 1-102 days). Mean hospital bill incurred per one admission day was ₩386,225.64 (345.77 USD). Approximately 96.9% of all hospitalizations were discharged routinely following treatment; of those that were not routinely discharged, 1.3% were discharged against medical advice, 0.8% were transferred to another hospital, and 1.0% died of the disease.

Table 1. Descriptive statistics of the study population (n=390)

Variable	Value
Sex	
Male	205 (52.6)
Female	185 (47.4)
Age (yr)	54.69±20.83
Ethnicity	
Korean	382 (97.9)
Not Korean	8 (2.1)
Insurance	
NHI	363 (93.1)
Medial aid	23 (5.9)
Not insured	4 (1.0)
Admission year	
2011-2012	69 (17.7)
2013-2014	65 (16.7)
2015-2016	88 (22.6)
2017-2018	81 (20.8)
2019-2020	87 (22.3)
Medically compromised	
Present	230 (59.0)
Not present	160 (41.0)
No. of comorbidities	1.21±1.33
Smoking	
Yes	251 (64.4)
No	139 (35.6)
Route of admission	
ER	325 (83.3)
Outpatient clinic	65 (16.7)
Hospital arrival time	
Day	265 (67.9)
Evening	89 (22.8)
Night	36 (9.2)
Time from symptomatic onset to hospitalization (day)	7.23±7.97
Time from onset of symptoms to first surgery (day)	7.89±7.55
Time from admission to first surgery (day)	0.78±1.79
Odontogenic etiology	
Yes	379 (97.2)
No	11 (2.8)
No. of infected spaces	2.16±1.47
Location of infection	
Single	355 (91.0)
Middle	9 (2.3)
Both	26 (6.7)
Deep neck infection	
Present	339 (86.9)
Not present	51 (13.1)
Fasciitis	
Present	377 (96.7)
Not present	13 (3.3)
Flynn score	4.13±3.13
Admission C-reactive protein level (mg/dL)	13.12±10.25
Admission white blood cell count (×1,000 cells/μL)	13.91±5.40
Admission blood glucose level (mg/dL)	140.25±70.05
Admission temperature	
<37.5°C	326 (83.6)
>37.5°C	64 (16.4)
Peak temperature during stay	
<37.5°C	241 (61.8)
>37.5°C	149 (38.2)
Antibiotic regimen	
Single (amoxicillin-sulbactam or ceftriaxone sodium hydrate)	35 (9.0)
Double (amoxicillin-sulbactam/ceftriaxone sodium hydrate+clindamycin)	288 (73.8)
Triple 1 (amoxicillin-sulbactam/ceftriaxone+clindamycin+metronidazole)	36 (9.2)
Triple 2 (amoxicillin-sulbactam/ceftriaxone+clindamycin with quinolones/amikacin)	21 (5.4)
Use of vancomycin or meropenem with concomitant use of other antibiotics	10 (2.6)

Table 1. Continued

Variable	Value
I&D	
Performed	321 (82.3)
Not performed	69 (17.7)
Tracheostomy	
Performed	13 (3.3)
Not performed	377 (96.7)
Surgery after admission	
Performed	261 (66.9)
Not performed	129 (33.1)
General anesthesia	
Performed	148 (37.9)
Not performed	242 (62.1)
Additional surgery	
Performed	71 (18.2)
Not performed	319 (81.8)
Additional trip to OR	
Yes	17 (4.4)
No	373 (95.6)
No. of OR uses	0.43±0.60
Length of GA	20.80±39.95
No. of operations	1.05±0.66
Operation type	
None	62 (15.9)
I&D alone	262 (67.2)
I&D & extraction (without other surgery)	30 (7.7)
I&D & surgery (other than extraction or tracheostomy)	20 (5.1)
I&D & tracheostomy (with or without other surgeries)	9 (2.3)
Other surgeries (with or without extraction) without I&D	7 (1.8)
Location of surgery	
Outpatient clinic before admission	67 (17.2)
ER	37 (9.5)
Outpatient clinic after admission	68 (17.4)
OR	156 (40.0)
No surgery	62 (15.9)
ICU use	
Yes	46 (11.8)
No	344 (88.2)
Length of ICU stay (day)	1.12±6.09
Length of hospital stay (day)	11.47±10.62
Total bill (Korean Won)	4,710,017.25±386,225.64 (\$4,216.67)
Average bill per one hospital day (Korean Won)	386,225.64±188,833.73 (\$345.77)
Treatment outcome	
Total recovery	378 (96.9)
Discharge against medical advice	5 (1.3)
Transfer to another hospital	3 (0.8)
Death	4 (1.0)

(NHI: National Health Insurance, ER: emergency room, I&D: incision and drainage, OR: operation room, GA: general anesthesia, ICU: intensive care unit)

Values are presented as number (%) or mean±standard deviation.

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8. Univariable and multivariable analyses

Univariate analysis results regarding the associations between the independent variables and LOS, total hospital bill, average hospital bill per day, ICU stay, and discharge outcomes other than routine discharge are summarized in Table 2.

Table 2. P-values from univariable analyses of selected variables (n=390)

Independent variable	Length of stay	Total hospital bill	Average bill per day (log ₂)	ICU stay	Other outcomes vs complete recovery
Sex (binary)	0.01 ^{1,*}	0.132 ¹	0.125 ¹	0.189 ²	0.857 ²
Age (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	0.024 ^{3,*}	<0.001 ^{1,*}	0.001 ^{1,*}
Ethnicity (binary)	0.47 ⁴	0.718 ⁴	0.065 ⁴	0.241 ²	>0.999 ²
Insurance (categorical)	0.74 ⁵	0.024 ^{5,*}	0.006 ^{5,*}	0.028 ^{6,*}	0.118 ⁶
Admission year (categorical)	0.02 ^{7,*}	<0.001 ^{7,*}	<0.001 ^{7,*}	0.323 ⁵	0.080 ⁶
Medically compromised (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	0.023 ^{1,*}	0.002 ^{2,*}	0.133 ²
No. of comorbidities (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{1,*}	0.04 ^{1,*}
Smoking (binary)	0.967 ¹	0.767 ¹	0.633 ¹	0.599 ²	0.761 ²
DM (binary)	0.022 ^{1,*}	0.009 ^{1,*}	0.655 ¹	0.374 ²	>0.999 ²
Endocrine disease (binary)	0.004 ^{1,*}	0.001 ^{1,*}	0.221 ¹	0.109 ²	0.202 ²
Cardiovascular disease (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	0.065 ¹	0.031 ^{2,*}	0.018 ^{2,*}
Neural disease (binary)	0.098 ⁴	0.028 ^{4,*}	0.169 ⁴	0.041 ^{2,*}	0.028 ^{2,*}
Route of admission (binary)	0.004 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	0.005 ^{2,*}	0.23 ²
Hospital arrival time (categorical)	0.432 ⁷	0.072 ⁷	0.103 ⁷	0.190 ⁶	0.155 ⁶
Time from symptomatic onset to hospitalization (continuous)	0.518 ³	0.179 ³	0.582 ³	0.424 ¹	0.707 ¹
Time from onset of symptoms to first surgery (continuous)	0.625 ³	0.736 ³	0.405 ³	0.444 ¹	0.348 ¹
Time from admission to first surgery (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	0.179 ³	0.656 ¹	0.346 ¹
Etiology (binary)	0.02 ^{4,*}	0.003 ^{4,*}	0.177 ⁴	>0.999 ²	>0.999 ²
No. of infected spaces (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{1,*}	0.107 ¹
Location of infection (categorical)	0.003 ^{7,*}	<0.001 ^{7,*}	0.059 ⁷	<0.001 ^{6,*}	0.612 ⁶
Deep neck infection (binary)	0.005 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{2,*}	0.198 ²
Fasciitis (binary)	0.013 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	0.056 ²
Flynn score (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{1,*}	0.207 ¹
Admission C-reactive protein level (mg/dL) (continuous)	0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{1,*}	0.155 ¹
Admission white blood cell count (×1,000 cells/μL) (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{1,*}	0.018 ^{1,*}
Admission blood glucose level (mg/dL) (continuous)	0.001 ^{3,*}	0.001 ^{3,*}	0.695 ³	0.266 ¹	0.808 ¹
Admission temperature (binary)	0.126 ¹	0.009 ^{1,*}	0.036 ^{1,*}	0.143 ²	0.699 ²
Peak temperature during stay (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{2,*}	0.066 ²
Antibiotic regimen (categorical)	<0.001 ^{7,*}	<0.001 ^{7,*}	<0.001 ^{7,*}	<0.001 ^{6,*}	0.002 ^{6,*}
I&D (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	0.026 ^{1,*}	0.003 ^{2,*}	0.452 ²
Tracheostomy (binary)	0.001 ^{1,*}	<0.001 ^{1,*}	0.001 ^{1,*}	<0.001 ^{1,*}	>0.999 ²
Surgery after admission (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{2,*}	0.758 ²
GA (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{2,*}	0.383 ²
Additional surgery (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	0.129 ¹	0.005 ^{2,*}	0.440 ²
Additional trip to the OR (binary)	<0.001 ^{1,*}	<0.001 ^{4,*}	<0.001 ^{4,*}	<0.001 ^{2,*}	0.091 ²
No. of OR visits (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{1,*}	0.158 ¹
Length of operation under GA (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	0.008 ^{3,*}	<0.001 ^{1,*}	0.779 ¹
No. of operations performed (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	0.034 ^{3,*}	0.008 ^{3,*}	0.830 ¹
Operation type (categorical)	<0.001 ^{7,*}	<0.001 ^{7,*}	0.001 ^{7,*}	<0.001 ^{6,*}	0.611 ⁶
Location of surgery (categorical)	<0.001 ⁷	<0.001 ⁷	<0.001 ⁷	<0.001 ^{6,*}	0.234 ⁶
ICU use (binary)	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{1,*}	<0.001 ^{2,*}	<0.001 ^{2,*}
Length of stay in ICU (continuous)	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	<0.001 ^{3,*}	0.070 ¹

(ICU: intensive care unit, DM: diabetes mellitus, I&D: incision and drainage, GA: general anesthesia, OR: operation room)

*P<0.05.

P-value calculated by ¹simple t-test, ²Pearson's chi-square test, ³Pearson correlation analysis, ⁴Mann-Whitney test, ⁵Kruskal-Wallis test (post-hoc analysis with Mann-Whitney), ⁶Pearson's chi-square test for each categorical group versus other subjects, ⁷one-way ANOVA (post-hoc analysis with Tukey test).

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Significant variables in the initial univariable analysis were entered into the preliminary multiple regression model. To adjust for clustering of outcomes, the number of infected spaces, medical compromise, diabetes, incision and drainage, GA, additional surgery, and ICU use were eliminated from the multiple regression models for LOS, total hospital bill, average bill per one admission day, and ICU use.

Results of the final multivariate regression models after removal of variables that were no longer significant after

controlling for other variables are summarized in Tables 3-7. Multivariable regression analysis revealed that 85.8% of the variation in length of hospital stay was due to different admission years, infection location, Flynn score, presence of deep neck infection, cardiovascular disease, admission CRP level, serum glucose level, length and number of surgeries, tracheostomy, time from admission to first surgery, and length of ICU stay.(Table 3) The variables of age, type of insurance, admission year, number of comorbidities, Flynn score, ad-

Table 3. Final multiple linear regression analysis for length of stay

Value name	β coefficient	95% CI	P-value
(Constant)	-5.527	-9.016 to -2.038	0.002*
Admission year			
2011-2012	Ref.	N/A	N/A
2017-2018	3.591	1.087 to 4.337	<0.001*
2015-2016	2.712	1.960 to 5.222	0.001*
Infection location			
Both	Ref.	N/A	N/A
Single	2.65	0.157 to 5.142	0.037*
Flynn score	0.625	0.337 to 0.912	<0.001*
Presence of deep neck infection	-3.765	-6.035 to -1.495	0.001*
Presence of cardiovascular disease	3.317	2.010 to 4.624	<0.001*
Admission C-reactive protein level	0.139	0.065 to 0.213	<0.001*
Admission blood glucose level	0.013	0.004 to 0.022	0.005*
Length of operation under GA	0.064	0.042 to 0.086	<0.001*
No. of operations performed	2.647	1.311 to 3.983	<0.001*
Tracheostomy performed	6.952	2.616 to 11.287	0.002*
Time from admission to first surgery	0.99	0.620 to 1.360	<0.001*
Length of ICU stay	0.66	0.534 to 0.786	<0.001*
R value	0.858		

(CI: confidence interval, Ref.: reference, N/A: not applicable, GA: general anesthesia, ICU: intensive care unit)

* $P < 0.05$.

The following variables were eliminated from the multivariable analysis model to adjust for clustering of outcomes: number of infected spaces, medically compromised, diabetes mellitus, incision and drainage, GA performed, additional surgery performed, ICU use.

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Table 4. Final multiple linear regression analysis for total amount billed (\log_2 value)

Value name	β coefficient	95% CI	P-value
(Constant)	20.091	19.420 to 20.761	<0.001*
Age	0.008	0.005 to 0.012	<0.001*
Type of insurance			
Not insured	Ref.	N/A	N/A
Medial aid	-1.173	-1.833 to -0.513	0.001*
NHI	-0.793	-1.407 to -0.179	0.012*
Admission year			
2011-2012	Ref.	N/A	N/A
2019-2020	0.578	0.413 to 0.744	<0.001*
2017-2018	0.524	0.359 to 0.689	<0.001*
2015-2016	0.292	0.124 to 0.459	0.001*
No. of comorbidities	0.082	0.027 to 0.136	0.003*
Flynn score	0.037	0.015 to 0.060	0.001*
Admission C-reactive protein level	0.02	0.013 to 0.026	<0.001*
Admission white blood cell count	0.019	0.007 to 0.031	0.002*
Admission blood glucose level	0.001	0.000 to 0.002	0.038*
Admission body temperature $>37.5^\circ\text{C}$	-0.201	-0.388 to -0.014	0.035*
Peak body temperature $>37.5^\circ\text{C}$	0.321	0.163 to 0.479	<0.001*
Surgery performed after admission	0.76	0.552 to 0.968	<0.001*
Type of surgery			
I&D alone	Ref.	N/A	N/A
Other surgery without I&D	-0.42	-0.828 to -0.013	0.043*
Length of surgery under GA	0.005	0.003 to 0.007	<0.001*
I&D location			
Operation room	Ref.	N/A	N/A
Outpatient clinic after admission	-0.569	-0.764 to -0.374	<0.001*
ER	-0.465	-0.703 to -0.227	<0.001*
Tracheostomy performed	0.595	0.218 to 0.972	0.002*
Time from admission to first surgery	0.069	0.032 to 0.106	<0.001*
Length of ICU stay	0.031	0.018 to 0.043	<0.001*
R value	0.904		

(CI: confidence interval, Ref.: reference, N/A: not applicable, NHI: National Health Insurance, I&D: incision and drainage, GA: general anesthesia, ER: emergency room, ICU: intensive care unit)

* $P < 0.05$.

The following variables were eliminated from the multivariable analysis model to adjust for clustering of outcomes: number of infected spaces, medically compromised, diabetes mellitus, incision and drainage, GA performed, additional surgery performed, ICU use.

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mission CRP, WBC, serum glucose, admission temperature, peak temperature, surgery after admission, type, length, and location of surgery, tracheostomy, time from admission to

first surgery, and length of ICU stay accounted for 90.4% of the variation in the total hospital bill.(Table 4) Significant variables accounting for 73.8% of the variation in the average

Table 5. Final multiple linear regression analysis for average bill per one admission day (log₂ value)

Value name	β coefficient	95% CI	P-value
(Constant)	18.67	18.237 to 19.102	<0.001*
Age	0.002	0.000 to 0.004	0.019*
Type of insurance			
Not insured	Ref.	N/A	N/A
Medical aid	-1.198	-1.618 to -0.779	<0.001*
NHI	-0.991	-1.379 to -0.603	<0.001*
Admission year			
2011-2012	Ref.	N/A	N/A
2013-2014	0.153	0.018 to 0.289	0.027*
2015-2016	0.212	0.081 to 0.343	0.002*
2017-2018	0.277	0.146 to 0.408	<0.001*
2019-2020	0.825	0.699 to 0.951	<0.001*
Presence of deep neck infection	0.174	0.052 to 0.297	0.005*
Admission white blood cell count	0.012	0.004 to 0.020	0.004*
Peak body temperature >37.5°C	0.117	0.026 to 0.208	0.012*
No. of operations under GA	0.184	0.094 to 0.275	<0.001*
Location of surgery			
OR	Ref.	N/A	N/A
Outpatient clinic before admission	-0.148	-0.261 to -0.035	0.011*
ER	0.181	0.037 to 0.325	0.014*
Length of ICU stay	0.016	0.009 to 0.023	<0.001*
R value	0.738		

(CI: confidence interval, Ref.: reference, N/A: not applicable, NHI: National Health Insurance, GA: general anesthesia, OR: operating room, ER: emergency room, ICU: intensive care unit)

*P<0.05.

The following variables were eliminated from the multivariable analysis model to adjust for clustering of outcomes: number of infected spaces, medically compromised, incision and drainage, GA performed, ICU use.

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Table 6. Final multiple logistic regression analysis for use of ICU

Value name	β coefficient	95% CI	P-value
(Constant)	-5.947	N/A	<0.001*
Age	1.029	0.995 to 1.063	0.094
Route of admission			
ER	<0.001	<0.001	0.996
Side			
Both	Ref.	N/A	N/A
Single	0.157	0.036 to 0.687	0.014*
No. of comorbidities	1.787	1.202 to 2.655	0.004*
Peak body temperature >37.5°C	10.136	2.922 to 35.164	<0.001*
Length of operation under GA	1.047	1.027 to 1.067	<0.001*
Type of surgery			
I&D alone	Ref.	N/A	N/A
I&D+other surgery	0.015	<0.001 to 0.591	0.025*
Tracheostomy performed	2.61	<0.001	0.997
Nagelkerke R ² value	0.684		

(ICU: intensive care unit, CI: confidence interval, ER: emergency room, Ref.: reference, N/A: not applicable, GA: general anesthesia, I&D: incision and drainage)

*P<0.05.

The following variables were eliminated from the multivariable analysis model to adjust for clustering of outcomes: number of infected spaces, medically compromised, I&D, GA performed, additional surgery performed.

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Table 7. Final multiple logistic regression analysis for other outcomes versus complete recovery

Value name	β coefficient	95% CI	P-value
(Constant)	-8.16	N/A	<0.001*
Age	1.064	1.012 to 1.118	0.014*
Use of ICU	7.727	2.239 to 26.666	0.001*
Nagelkerke R ² value	0.253		

(CI: confidence interval, N/A: not applicable, ICU: intensive care unit)

*P<0.05.

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bill per one admission day were age, insurance, admission year, deep neck infection, admission WBC, peak temperature, number and location of surgeries performed, and length of ICU stay.(Table 5) Only infection location, number of comorbidities, peak temperature, and length and type of surgery had a significant association with stay in the ICU in the final multiple logistic regression analysis. Age, route of admission, and performance of tracheostomy were included in the final regression model, but had P-values higher than 0.05 and were

thus considered to be non-significant variables.(Table 6) The only two variables that showed a significant association with discharge outcomes in the final multiple logistic regression analysis were age and ICU use.(Table 7)

IV. Discussion

In this retrospective study, we sought to describe the demographics, treatment outcomes, and hospital costs of patients with severe maxillofacial infections requiring admission at a tertiary center in South Korea and to assess the associations between treatment outcomes and diverse social, patient health, and treatment-related variables. To the best of our knowledge, this is the first study to document the financial outcomes and associated factors of patients hospitalized for maxillofacial infections in an Asian country.

1. Demographic characteristics

Mean age of occurrence for severe maxillofacial infections requiring hospitalization was 54.69 years. This is a significantly older age than reported in previous studies^{1-3,5-8,11-18}, which reported severe maxillofacial infections around the fourth and fifth decades of life. This is also higher than the reported mean age of 47.13 years in a previous Korean study by Park and colleagues on maxillofacial patients who presented to the ER¹⁷. The relatively older average age of the patients in the present study can be attributed to the rapid aging of the Korean population in the recent years, which has been reported to be the fastest among OECD (Organisation for Economic Co-operation and Development) countries, with the share of the population aged 65 and above expected to exceed one-third by 2050¹⁹. Therefore, it is essential that surgeons pay special attention to the oral health care of the older members of society as they are at higher risk of developing severe maxillofacial infections.

Many patients had multiple comorbidities. The high rate of patients with at least one comorbid condition (59%) is in accordance with the findings of previous studies^{1,2,5}. In light of these findings, Abramowicz et al.¹ recommended that orofacial infections in medically compromised patients be identified as early as possible to make the early delivery of antibiotics and surgical intervention possible.

Most cases in the current study (97.2%) were due to odontogenic causes. This is in accordance with a previous Korean review that reported the rate of maxillofacial infections due to odontogenic infections in Korea to be 92.47%¹⁷. However,

this figure is much higher than those previously documented by other researchers for hospitalized patients of 61.8% to 71.0%^{7,13,14,16,20}. This is probably due to the nature of the present study, in which only patients admitted to the oral and maxillofacial department were included in the statistical analysis. To focus on non-odontogenic infections, future studies should also include patients admitted to the ENT department.

2. Treatment outcomes

Average LOS in this study was 11.47 days. While this is in accordance with studies conducted in South Korea^{17,21,22} and other Eastern countries^{18,20}, this was a nearly two- to four-fold higher rate than the figures reported for Western populations. A previous study based on national data that investigated the treatment outcomes of patients in the USA admitted with mouth cellulitis reported an average LOS of only 3.9 days¹². Other Western studies reported similar results, with the mean LOS ranging from 2.96 to 5.46 days^{1,2,5,9,10,23}.

However, despite the overwhelmingly longer period of hospital stay observed among our population, the mean hospital expenditure was only \$4,216.67. This is in stark contrast to the reported mean hospital charges in previous USA reports of \$14,245 to \$48,351^{1,2,5,6,8-10,12,23}. This figure is also lower than that reported in one previous British study on the cost outcomes of hospitalization of deep neck infections, which is the only study in the literature that documents the hospital costs related to maxillofacial infections outside of the USA⁷. The authors of that study reported a mean LOS of 11 days and a mean hospital charge of \$7,562⁷.

The prolonged admission period and low treatment costs of the current study can be attributed to Korea's unique NHI Program and the accessibility of medical services. The NHI Program is a universal social insurance program that oversees all health care in the Republic of Korea. It is compulsory by law, and thus covers the entire population residing in the Korean domain^{24,25}. It is operated by a single insurer, the NHI Service (NHIS), which operates under supervision of the Korean government. Under this insurance program, the entire population is entitled to only a portion of medical utilization costs²⁴. Approximately 3.7% of the population in the low-income bracket are also assisted by a free medical aid program and can use medical services free of charge²⁵. South Korea thus boasts 100% accessibility to necessary health care services, which is in stark contrast to the accessibility value reported for the United States of 90.8% as reported by the OECD in 2019¹⁹. The high ratio (99%) of the insured popula-

tion in the current study implies exceptional access to medical services, in contrast to the values reported in previous studies in the USA of 16.9% to 82.5%^{1,2,5,10,12,23}.

The substantially lower costs reported in this study are also consistent with medical costs in South Korea reported in previous OECD reports, in which the comparative average price level for health was only 48% of that of the USA and 24% lower than the OECD average health cost¹⁹.

However, other recent OECD reviews of the South Korean medical system have all identified over-provision of hospital admissions to be a major quality issue²⁶. Sohn and Jung²⁴ attributed this phenomenon to the 'moral hazard' model, which refers to the trend in which patients use medical services more than is necessary or are negligent in health promotion due to low out-of-pocket costs. The significantly longer duration of hospital stay in the current study compared to previous studies may also be due to this trend. Therefore, future treatment of maxillofacial infections in the South Korean population should focus on the prevention of severe infections and the establishment of efficient treatment protocols such as prompt surgical interventions.

In our study, the vast majority of cases were routinely discharged following complete recovery (96.9%), and the mortality rate was only 1.0%. This recovery rate is substantially higher than the 88% documented in a 2008 USA study based on nationwide data¹². This relatively high rate of recovery may also be due to the ease of access and relatively low burden of Korean medical services. Because most patients are covered by the NHI, patients may present to the hospital earlier in their disease course, a more aggressive treatment approach may be followed, and length of care is not a consideration, all of which would increase the probability of complete resolution of the infection. A similar finding was reported in a previous study by Yew et al.¹⁶, who attributed the low rates of severe complications and mortality among patients with orofacial infections in their study to the affordability and accessibility of the Malaysian public healthcare service. The poor oral health status and treatment outcomes among populations at the lower end of the socioeconomic scale, and the need for improved access to healthcare for this socioeconomic group have been emphasized in a recent report by Kruger and Tennant²⁷.

3. Factors significantly associated with treatment outcomes

Although many researchers have sought to identify variables associated with the treatment outcomes of maxillofacial infections via univariable analysis, few studies have used multivariable analysis to identify potential relevant prognostic factors. We argue that the outcomes of maxillofacial infections cannot be predicted by one factor alone but are likely affected by patient-, disease-, and treatment-related factors. The complex nature of maxillofacial infections is highlighted in this study by our finding that most independent variables were significantly associated with outcome variables in initial univariable analysis but were later excluded after controlling for other variables.

In this study, 85.8% of the total variation in LOS was explained by the multivariable regression model, which is a relatively higher prediction value than those reported previously of 32.8% to 68.2%^{3,13}. The rates of variation in total hospital bill (90.4%), average hospital bill per day (73.8%), and prevalence of ICU stay (68.4%) in the final regression analysis models were also relatively higher than reported in similar studies^{3,23}. The multivariable model in the study by Flynn et al.²⁸ reported a similar ratio of variability in LOS (84%) to that reported in this study, but the study population comprised only 37 subjects.

Not surprisingly, variables related to involvement of multiple anatomical sites such as infection side, Flynn score, and presence of deep neck infection were significantly correlated with longer LOS and higher costs. The association between multi-space infections and longer stay in the hospital in addition to higher hospital bills has been documented in several previous reports^{3,12,17,28}. We also found that a delay in surgical intervention was associated with a longer stay, indicating the importance of prompt surgery when deemed necessary.

Of note is our finding that admission serum glucose level was significantly associated with overall LOS and hospital costs. The significant correlation between elevated serum glucose level due to diabetes and longer hospital stay, increased possibility of severe complications, and poorer treatment outcomes of maxillofacial infection patients has been documented in several previous studies^{3,12,17,20}. This relationship has been attributed to poor tissue perfusion with a subsequent delay in wound healing and immune system dysregulation^{5,20}. Other health-related variables such as elevated WBC level and body temperature were also associated with increased hospital costs.

Factors that were significantly associated with ICU stay were the location of infection, number of comorbidities, peak temperature, length of operation, and type of surgery. Similar correlations were reported by Christensen et al.³ who also performed a multivariate logistic regression analysis.

In the present study, 25.3% of discharge outcomes other than complete recovery could be predicted by the final multiple logistic regression analysis model. Although nearly 75% of unfavorable discharge outcomes could not be explained, age and use of the ICU were significantly associated with an unfavorable discharge outcome. Among these two variables, stay in the ICU is an unavoidable complication of a severe infection. Our study results therefore suggest that older age is the only significant variable associated with a poor treatment outcome. Meticulous attention must thus be paid when treating the older population suffering from severe maxillofacial infections as this population is at increased risk of life-threatening complications, prolonged stay in the ICU, and death.

4. Limitations and strengths

As a retrospective chart review, this study has several limitations. Due to its retrospective nature, the possibility of misleading or inaccurate records cannot be ruled out. Furthermore, as mentioned above, we were only able to demonstrate significant associations between variables and outcomes, not cause and effect. Furthermore, the study was limited to patients treated in a single tertiary center and may therefore not be nationally representative.

Despite these shortcomings, the current study is the first study to investigate factors associated with the hospital costs of maxillofacial infections in an Asian country based on multivariable analysis of a relatively heterogeneous population of 390 patients.

V. Conclusion

Although the mean total hospital expenditure for patients with maxillofacial infections was much lower in our South Korean patient population than reported for Western countries, the mean length of hospital stay was much longer, and the rate of complete recovery much higher, suggesting overprovision of hospital services for the treatment of maxillofacial infections. This emphasizes the importance of optimizing accessibility to medical services to obtain the best treatment outcomes.

For patients hospitalized with maxillofacial infections, the

following should be taken into consideration.

1. To limit LOS, meticulous attention must be paid to the timing, duration, and number of appropriate surgical interventions, appropriate ICU use, and overall determination of the patient's health status and infection severity.

2. Hospital costs are significantly influenced by factors related to insurance, patient's initial status upon admission, ICU use, and the timing, duration, type, location, and number of appropriate surgical interventions.

3. Special attention must be paid when treating old patients suffering from maxillofacial infections, for the only key variable impacting treatment outcome is patient age.

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Authors' Contributions

H.W.K. participated in data collection, performed the statistical analysis, and wrote the manuscript. C.H.K. participated in the study design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

The study was approved by the Institutional Review Board of Dankook Dental University Hospital (No. DKUDH IRB 2020-09-007), and the informed consent was waived by the IRB.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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