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Surgical complexity score as a predictor of surgical site infection in dentoalveolar surgeries

Índice de complexidade cirúrgica como preditor de infecção do sítio cirúrgico em cirurgias dentoalveolares

Score de complejidad quirúrgica como predictor de infección del sitio quirúrgico en cirugías dentoalveolares

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Abstract
Introduction: Postoperative surgical site infections represent one of the most frequent complications related to health care and can increase morbidity and mortality, in addition to increasing treatment costs. Objectives: This study evaluated surgical site infections incidence after dentoalveolar surgeries of retained third molars. The article presents the development of a surgical complexity score that can be used as a predictive method for surgical site infections risk in dentoalveolar surgeries. Methodology: In this cross-sectional observational study, the sample was obtained for convenience, from medical records of patients diagnosed with tooth retention and who underwent dentoalveolar surgery of third molars, from 2015 to 2020. Demographic variables of patients, characteristics of the surgery and information regarding the diagnosis of surgical site infections in the postoperative period were collected. Results: A total of 360 medical records were analyzed, with 59 surgical site infection cases diagnosed (16.4%). There was a statistical difference ($p<0.05$) in the bivariate analysis correlating infection with time of procedure, type of incision and performance of ostectomy and tooth sectioning. Logistic regression analysis to identify the probability of infection showed no significance for any of the individual variables, except when they are combined composing the surgical complexity score, which was then significantly higher in surgical site infections cases. Conclusions: The surgical complexity score developed can be a new predictive tool for the occurrence of surgical site infections in dentoalveolar surgeries, taking into account that the greater the complexity of surgery, the greater risk.
Keywords: Infection of surgical wound; Oral surgery; Third molar.

Resumo
Introdução: As infecções pós-operatórias de sítio cirúrgico representam uma das complicações mais frequentes relacionadas à assistência à saúde e podem aumentar a morbimortalidade, além de elevar os custos do tratamento. Objetivos: Este estudo avaliou a incidência de infecções de sítio cirúrgico após cirurgias dentoalveolares de terceiros molares retidos. O artigo apresenta o desenvolvimento de um escore de complexidade cirúrgica que pode ser utilizado como método preditivo do risco de infecção de sítio cirúrgico em cirurgias dentoalveolares. Metodologia: Neste

estudo observacional transversal, a amostra foi obtida por conveniência, a partir das histórias clínicas de pacientes com diagnóstico de retenção dentária e que foram submetidos à cirurgia dentoalveolar de terceiros molares, no período de 2015 a 2020. Variáveis demográficas dos pacientes, características da cirurgia e informações sobre o diagnóstico de infecções pós-operatórias do sítio cirúrgico foram coletadas. Resultados: Foram analisados 360 prontuários, sendo diagnosticados 59 casos de infecção de sítio cirúrgico (16,4%). Houve diferença estatística ($p<0,05$) na análise bivariada que correlacionou a infecção com o tempo do procedimento, o tipo de incisão e a realização da ostectomia e odontossecção. A análise de regressão logística para identificar a probabilidade de infecção não mostrou significância para nenhuma das variáveis individualmente, exceto quando combinadas para compor o escore de complexidade cirúrgica, que foi significativamente maior para infecções de sítio cirúrgico. Conclusões: O escore de complexidade cirúrgica desenvolvido pode ser uma nova ferramenta preditiva para a ocorrência de infecções de sítio cirúrgico em cirurgias dentoalveolares, tendo em vista que quanto maior a complexidade da cirurgia, maior o risco.
Palavras-chave: Infecção da ferida cirúrgica; Cirurgia bucal; Terceiro molar.

Resumen
Introducción: Las infecciones del sitio quirúrgico posoperatorio representan una de las complicaciones más frecuentes relacionadas con el cuidado de la salud y pueden aumentar la morbimortalidad, además de incrementar los costos del tratamiento. Objetivos: Este estudio evaluó la incidencia de infecciones del sitio quirúrgico después de cirugías dentoalveolares de terceros molares retenidos. El artículo presenta el desarrollo de un score de complejidad quirúrgica que puede ser utilizado como método predictivo del riesgo de infecciones del sitio quirúrgico en cirugías dentoalveolares. Metodología: En este estudio observacional de corte transversal, la muestra se obtuvo por conveniencia, de las historias clínicas de los pacientes con diagnóstico de retención dental y que se sometieron a cirugía dentoalveolar de terceros molares, del 2015 al 2020. Variables demográficas de los pacientes, características de la cirugía y se recolectó información sobre el diagnóstico de infecciones del sitio quirúrgico en el postoperatorio. Resultados: Se analizaron un total de 360 historias clínicas, diagnosticándose 59 casos de infección del sitio quirúrgico (16,4%). Hubo diferencia estadística ($p<0,05$) en el análisis bivariado que correlacionó la infección con el tiempo del procedimiento, el tipo de incisión y la realización de la ostectomía y la odontosección. El análisis de regresión logística para identificar la probabilidad de infección no mostró significación para ninguna de las variables individuales, excepto cuando se combinan para componer el puntaje de complejidad quirúrgica, que luego fue significativamente mayor en los casos de infecciones del sitio quirúrgico. Conclusiones: El score de complejidad quirúrgica desarrollado puede ser una nueva herramienta predictiva para la ocurrencia de infecciones del sitio quirúrgico en cirugías dentoalveolares, teniendo en cuenta que a mayor complejidad de la cirugía mayor riesgo.
Palabras clave: Infección de la herida quirúrgica; Cirugía bucal; Tercer molar.

1. Introduction

Healthcare-associated infections (HAIs) are unintended consequences of care that, in addition to increasing morbidity and mortality, can increase the patient's hospitalization time as well as treatment costs, either for the patient or for the health system (Fuglestad et al., 2021; Rice *et al.*, 2023; Sahtoe *et al.*, 2021; Tesini & Dumyati, 2023; Totty *et al.*, 2021; Yokoe *et al.*, 2008). Surgical site infections (SSIs), one of the most frequent types of HAIs (Delgado-Rodríguez et al., 2001; Mengistu *et al.*, 2023), are becoming more challenging due to a higher number of surgical procedures performed worldwide, the increasingly complex comorbidities seen in surgical patients and increased antimicrobial resistance (Sahtoe *et al.*, 2021).

Although SSIs are frequent complications that substantially increase costs for the health system (Fuglestad *et al.*, 2021; Sahtoe *et al.*, 2021), their role in Oral and Maxillofacial Surgery and Traumatology is poorly understood. This would be particularly important in the case of surgical removal of third molars, one of the most frequent elective procedures in this field (Chuang et al., 2007). The present study aims to fill this gap by evaluating the incidence of SSIs after dentoalveolar surgeries of third molars, with preoperative diagnosis of tooth retention, in a teaching hospital in Southern Brazil. The factors influencing the occurrence of this type of SSI were also investigated.

This research also presents the development of a new surgical complexity score (SCS) for dentoalveolar surgeries that can be used as a predictive method of postoperative infection in this type of surgery, clinically relevant for the implementation of guidelines to prevent or decrease the incidence of SSIs.

2. Methodology

This retrospective cross-sectional observational study (Estrela, 2018; Pereira et al., 2018) used information obtained from electronic medical records at Hospital de Clínicas de Porto Alegre, Rio Grande do Sul, Brazil. The convenience consecutive sample included the medical records of patients diagnosed with tooth retention and who underwent dentoalveolar surgery of third molars, at the Oral and Maxillofacial Surgery Service of the Hospital. The observation period was from January 2015 (the year in which the electronic medical records platform was implemented in the study hospital) to December 2020. Cases lacking data on important variables, or with incomplete medical records, were excluded. All the procedure was approved by the Research Ethics Committee of Hospital de Clínicas de Porto Alegre through Plataforma Brasil - reference no. 3.824.420.

Demographic variables of patients, characteristics of the surgery and information regarding the diagnosis of SSI in the postoperative period were collected. Data were collected by a single researcher, and the study was previously approved by the Research Ethics Committee of Hospital de Clínicas de Porto Alegre through Plataforma Brasil - reference no. 3,824,420. The data was entered into an electronic database-using Microsoft Excel version 15.0.

The sociodemographic variables included age, gender, city of origin (state capital – Porto Alegre – or interior city) and degree of education. The surgical variables were extracted teeth, type of incision, ostectomy, tooth sectioning, surgery time and ASA (American Society of Anesthesiologists) classification of the patient. SSI was diagnosed using the National Nosocomial Infection Surveillance System (NNIS) criteria (Emori *et al.*, 1991): presence of purulent secretion involving the incision site or in organs and cavities; microorganism-positive cultures from fluids or tissues collected from the surgical incision; local phlogistic signs, suture dehiscence and/or deliberate opening of the incision by the surgeon, except when the culture is negative; or diagnosis of infection, according to the affected site, by the surgeon or assistant professional.

2.1 Statistical analysis and composition of the surgical complexity score (SCS)

The data were organized descriptively through frequency tables, stating the relationship between the indicators of the study and SSI. The chi-square and Mann-Whitney nonparametric tests were used to identify significant associations between the SSI and the indicators. A value of $p<0.05$ was considered statistically significant. The analysis was performed with version 21.0 of IBM SPSS for Windows (IBM Corp, Armonk, NY, USA).

After analyzing the association between indicators and SSI, a surgical complexity score (SCS) was developed with the objective of making predictions for SSIs. The score takes into account the following indicators: extracted teeth; time of the procedure; type of incision; ostectomy; tooth sectioning; and patient ASA classification (Table 1).

Table 1 - SCS composition - variables, scores and bibliographic reference for inclusion of the variable.

Variable	SCS score range	Reference
Extracted teeth	1 – Only and upper third molar 2 - Two upper third molars 3 - Only a lower third molar 4 – A lower third molar plus one or two upper third molars 5 - Two lower third molars (associated or not with other teeth)	The simultaneous extraction of right and left lower third molars is associated with an increased risk of SSI (Sukegawa *et al.*, 2019).
Time of procedure	1 - Between 0 and 30 min 2 - Between 31 and 60 min 3 - Between 61 and 90 min 4 - Between 91 and 120 min 5 - More than 120 min	In risk scores for SSI pre-established in other surgical specialties, the duration of surgery was an important predictor for SSI (Gibbons *et al.*, 2011).
Tipe of incision	1 - Only sindesmotomy 2 - Only intrasulcular incision 3 - Neumann incision for access to a site (a tooth)	The SCS increases according to the amplitude of access and detachment, taking into account the hypothesis that the greater the need for wide access

	4 – Neumann incision for access to two sites (two teeth in the same session) 5 - Neumann incision for access to three or more sites (three or more teeth in the same session)	and detachment, the higher the degree of retention, with greater surgical invasion and higher SSI risk (Sukegawa *et al.*, 2019).
Ostectomy	1 - Not performed 3 - Performed in a single surgical site 5 - Performed at two or more surgical sites	The need for ostectomy is related to the increase in SSC (Sukegawa *et al.*, 2019).
Tooth sectioning	1 - Not performed 3 - Performed in a single surgical site 5 - Performed at two or more surgical sites	The need for tooth sectioning is related to the increase in SSC (Sukegawa *et al.*, 2019).
ASA classification	1 - ASA 1 3 - ASA 2 5 - ASA 3 and 4	The ASA classification is predictive for SSI in different surgical specialties (Bailey *et al.*, 2020; Chuang *et al.*, 2007).

Source: Authors.

Parameters used for making the SCS. The factors were ordinally categorized into intensity/complexity levels; thus, each item contributed proportionally to the SCS. SCS: surgical complexity score; SSI: Surgical site infections.

For these indicators, a scale was elaborated with scores ranging from 1 (lower degree of surgical difficulty) to 5 (higher degree of surgical difficulty). The SCS was obtained by adding the scores of the variables analyzed for each patient, with the same weight to all indicators. In this way, the lowest value that can be obtained in the index is 6 and the maximum is 30.

2.2 Conversion of the SCS from a 6 to 30 to a 0 to 100 scale

For a better interpretation of the SCS, the scale from 6 to 30 was converted to a scale 0 to 100, according the the equation below:

$$X\% = \left(\frac{X-6}{24}\right).100$$

Where x is the value obtained in the SCS (scale 6 to 30) and X% is the score in a scale 0 to 100.

To establish the probability of infection, and to identify the correlation of each indicator used in the preparation of the SCS and also with the SCS itself, binary logistic regression was used. SSI was considered the dependent variable, with the following categorization for infection: 0 = absence and 1 = presence.

3. Results

3.1 Sample characterization

A total of 360 medical records were analyzed, with 59 cases of SSI diagnosed (16.4%). The sample was predominantly female (69.2%); 30.3% of the patients were from Porto Alegre; 25.6% of the sample had no degree of academic education, while only 3.9% had completed higher education. Most of the patients (55.8%) were between 21 and 40 years of age, and were predominantly classified as ASA I (79.2%).

3.2 Association of SSIs with variables of the SCS study indicators

Bivariate analysis for the association of SSIs with the indicators extracted teeth, time of the procedure, and type of incision, ostectomy, tooth sectioning and ASA classification are presented in Table 2.

Table 2 - Chi-square values ($\chi 2$) and p-value of the Chi-square test for association between SSIs and study indicators.

Variable	Chi-square (χ^2)	Asymptotic (bilateral) significance – p value
Extracted teeth	7.396	0.116
Time of procedure	12.888	0.012*
Type of incision	11.557	0.021*
Ostectomy	12.767	0.002*
Tooth sectioning	6.590	0.037*
ASA classification	0.240	0.887

* Significant association (p<0.05). Source: Authors.

Only the procedure time, type of incision, presence of ostectomy, and tooth sectioning were significantly associated with surgical complexity score (p<0.05). This shows that the position of extracted teeth and the patient's physiological status are not related to the presence of postoperative infection.

The analysis showed a significant association (p<0.05) of incidence of SSI with the time of the procedure, type of incision, performance of ostectomy and tooth sectioning. However, no statistically significant associations with ASA classification of the patient and extracted teeth were observed.

3.3 Relationship between surgical complexity score and SSI incidence

The developed surgical complexity score included six variables – extracted teeth, time of procedure, type of incision, ostectomy, tooth sectioning, and ASA classification of patients, with grades 1 to 5 in each category. This SCS proved effective in predicting SSI risk, as shown below.

Table 3 presents a descriptive analysis of the SCS in the scale 0 to 100, which was used as the standard in this study.

Table 3 - Descriptive analysis of the SCS on the scale from 0 to 100.

Parameter	**SCS (0-100 scale)**
N	360
Mean	43.33
Standard deviation	21.84
Minimum	0
Maximum	100
Percentiles	
• 25%	25.00
• 50% (median)	41.67
• 75%	58.33

Source: Authors.

Despite the mean and median being located approximately at the central point of the indicator, the third quartile (75%) reaches 58.33 on the scale. This data indicates that most of the evaluated patients were positioned in values below 60%.

A significant association was found when comparing the SCS with the different outcomes of SSI by the Mann-Whitney test, with higher values on the SCS scale in cases with SSI incidence (U=0.6410.0; p=0.001) (Table 4).

Table 4 - Comparison of SCS between patients with different postoperative outcomes.

Statistical test	Result
Mann-Whitney U	6410.000
Wilcoxon W	51861.000
Z score	-3.384
Asymptotic (bilateral) significance	0.001*

* Significant association (p<0.05). Source: Authors.

Statistical differences between SCS values in the presence or absence of SSIs. The grouping variables consider presence of infection in the surgical site.

3.4 Sociodemographic variables and the relationship between SCS and SSI

In the investigation of the relationship of gender, city of origin, degree of education, age and SCS with SSI incidence, the only significant association observed was between SSI and SCS (p<0.05, Table 5).

Table 5 - Logistic regression results for sociodemographic variables and SCS with the occurrence of SSIs.

Variable	P-value	Standard error	Degrees of freedom	Odds ratio
Age	0.345	0.013	1	1.012
Gender	0.460	0.332	1	0.783
City of origin	0.442	0.314	1	0.786
Degree of education	0.151	0.173	1	1.282
SCS	0.001*	0.007	1	1.025
Constant	0.002	0.848	1	0.071

* Significant association (p<0.05). Source: Authors.

It is highlighted in the analysis that the variables that describe the profile of the evaluated patients are not significantly associated with the occurrence of SSIs.

In addition, Table 6 presents the results of logistic regression considering the SSI as dependent variable.

Table 6 - Logistic regression results for SCS variables and presence of SSIs.

Variable	P-value	Standard error	Degrees of freedom	Odds ratio
Extracted teeth	0.900	0.193	1	0.976
Time of procedure	0.921	0.193	1	1.019
Type of incision	0.905	0.247	1	0.971
Ostectomy	0.058	0.208	1	1.485
Tooth sectioning	0.903	0.120	1	1.015
ASA classification	0.451	0.149	1	1.119
Constant	0.000	0.704	1	0.046

* Significant association (p<0.05). Source: Authors.

Although the p-value only showed a tendency towards significance, Ostectomy was the variable that shows the highest association with the SCI.

Although bivariate analysis showed an association between the variables included in the SCS with SSI risk (Table 2), individual variables do not have the capacity to predict the occurrence of infection when analyzed jointly by logistic regression, as presented in Table 6. Taken as a whole the analyses show that only the aggregative mode of the effects of each of the variables composing the SCS significantly allows the prediction of SSI risk.

Logistic regression also shows that the SCS indicates the probability of infection. Thus, using the regression expression it is possible to identify that from a level of 75 in the indicator, a probability of 27% of infection is observed, reaching 39% when SCS is equal to 100.

4. Discussion

Surgical site infections are health-related infections widely studied in the medical field (Fisha et al., 2019; Fuglestad *et al*., 2021; Mengistu *et al.*, 2023; Ribeiro et al., 2007; Phan *et al.*, 2019), in the search for predictive factors that allow preventive measures to avoid this unfavorable outcome.

Surgery for removal of third molars is the most frequently performed procedure in Oral and Maxillofacial Surgery and Traumatology, and possible complications described in the literature include pain, edema, trismus, nerve damage, alveolar osteitis and postoperative infection (Oomens & Forouzanfar, 2012). Despite being a routine procedure for the specialty, few studies have analyzed the factors that influence the occurrence of SSI in the postoperative period in this type of surgery, so that the characteristics of affected patients and the causes that lead to SSI are not fully understood (Miyazaki *et al.*, 2023; Sukegawa *et al.*, 2019).

Considering the difficulty in establishing parameters that estimate the risk of SSI in dentoalveolar surgeries through preoperative imaging (Bali et al., 2013), the present study developed a surgical complexity score combining variables and determining the complexity of surgery, which from multivariate analyses proved effective to estimate the SSI risk (U=0.6410; p=0.001).

The SCS takes into account which third molar(s) was or were extracted in the procedure, the time used in the procedure, the type of incision used to access the site, the use of ostectomy and tooth sectioning for tooth removal and the ASA classification of the patient. These variables were selected due to their relationship with the occurrence of infection, as reported in other studies (Al-Asfour 2009; Bailey *et al.* 2020; Coulthard *et al*., 2014; Chuang *et al.*, 2007; Meyer et *al.*, 2011). Although it is convenient to work with original data, without loss of information, it was important to analyze the categorized data, since besides facilitating the interpretation; they are clinically relevant and can determine therapeutic approaches.

Other surgical specialties have already analyzed SSI risk indices, and risk factors included in the multivariate best-fit models varied according to the type of surgical procedure, as well as the effects of the factors included in the models (Gibbons *et al.*, 2011).

In pre-established SSI risk scores, the duration of surgery was an important factor for almost all procedures, and the ASA classification was a consistent risk factor for most surgical specialties, indicating the importance of these factors in the composition of the present SCS as a predictor of postoperative infection risk (Gibbons *et al.*, 2011).

In surgeries for removal of third molars, extended procedure time evaluated as a continuous variable showed high relationship with SSI risk in initial analyses with chi-square tests, losing some of the impact when adjusted with other variables (Benediktsdóttir et al., 2004). Therefore, procedure time seems to be an important variable as a predictive factor for SSI, but should be adjusted with other variables, as is the case with the present SCS.

The initial analysis of data with Pearson's chi-square test showed no significant relationship between the ASA classification of patients and SSI. However, since other studies propose that ASA classification is a predictive factor for SSI in different surgical specialties (Chuang *et al.*, 2007; Kaye *et al.*, 2001), and considering that the presence of comorbidities may complicate the surgical procedure and delay the process of tissue regeneration (Carvalho et al., 2017), it was included the ASA value in the composition of the SCS. In addition, the ASA classification composes the post-surgical infection risk score of the NISS (Carvalho *et al.*, 2017).

The simultaneous removal of right and left lower third molars is associated with an increased risk of SSI, as it may cause an increase in the severity of edema and trismus, leading to poor oral hygiene conditions and retention of food residues in surgical sites after dental removal, which theoretically would be the etiology of postoperative infection in these cases (Sukegawa *et al.*, 2019). Despite being poorly reported as risk factors in the literature, these findings support the importance of including in the SCS the number and location of teeth extracted per session. Therefore, the higher the number of sites addressed, or the more teeth extracted, the higher this item is in the score. In addition, lower third molars receive a higher risk score than the upper ones, since studies have shown a higher SSI risk when the lower third molars are extracted (Meyer *et al.*, 2011; Figueiredo et al., 2007; Sukegawa *et al.*, 2019).

For composing the SCS, the variable incision used to access the surgical site for removal of the third molars has increased value according to the amplitude of access and detachment. This decision takes into account the hypothesis that the greater the need for wide access and detachment, the greater the degree of tooth retention, which may indicate greater surgical invasion, with possible need for alveolar bone ostectomy and tooth sectioning techniques, which are also related to increased SSI risk (Sukegawa *et al.*, 2019). However, although a larger surgical incision contributes to a score of greater surgical complexity, some studies show that the incidence of postoperative complications after removal of third molars can be reduced with the planning of appropriate incisions and flaps (Mohajerani et al., 2018). The use of flaps with relaxing incisions for the removal of third molars increases postoperative edema, but does not necessarily increase the SSI risk (Kirk et al., 2007).

Tooth sectioning and retention depth are risk factors for SSI (Figueiredo *et al.*, 2007), so that ostectomy and tooth sectioning in the removal of the retained third molars increase the SCS. It is important to highlight that the ostectomy and tooth sectioning procedures of all surgeries included in this study were performed with rigorous maintenance of aseptic technique.

The SCS developed in this study presented a significant ($p<0.05$) association with SSI incidence, but no relationship was observed between any of the sociodemographic variables and SSI. These results differ from the literature, since there are reports of correlation between age and risk of postoperative complications (Akadiri & Obiechina, 2009), or between schooling and low socioeconomic status with SSI risk (da Cunha et al., 2011). This last result can be explained by a relationship of low schooling with more precarious care in the postoperative period.

The overall SSI incidence observed in this study was 16.4%, which seems to be a high rate compared to some studies that report surgical site infection rates around 0.5% to 3.00% (Chiapasco et al., 1993; Seidelman et al., 2023; Sukegawa *et al.*, 2019). However, it is noteworthy that these studies with a low SSI incidence used the prescription of antimicrobials in the postoperative period as a routine, different from our routine in which antimicrobials are prescribed prophylactically only in cases recommended by the guideline of the American Heart Association (AHA), or therapeutically in cases of infections already present in the postoperative period (Lodi *et al.*, 2012; Lodi *et al.*, 2021; Torof et al., 2023; Wilson *et al.*, 2021).

5. Conclusion

The surgical complexity score developed in the present study can be a new predictive tool for the occurrence of SSI in dentoalveolar surgeries, taking into account that the greater the complexity of surgery, the greater the SSI risk. The SCS may guide the surgeon in choosing preventive and/or therapeutic measures, reducing the likelihood of SSI.

As future directions, there is the possibility of refining the SCS by incorporating new parameters that have not been tested so far, such as biochemical factors that are routinely collected preoperatively. With these new adjustments, it will be possible to carry out a prospective investigation testing the SCS predictions postoperatively using a larger number of patients.

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