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Maxillofacial Fracture Trauma: Orbital Walls Fracture and their Association Using Multilayer Neural Network Perspectives

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ABSTRACT

Objective: This study aims to find the association of fractured orbital walls with other possible fractures reported in the maxillofacial trauma cases in the Oral Maxillofacial Clinic Oral Maxillofacial ward, Hospital USM Kelantan, Malaysia. ***Materials and methods:*** From 2013 to June 2018, records of patients who sustained maxillofacial fractures and presented them to the Accident and Emergency Department, Oral Maxillofacial Clinic, Hospital USM were reviewed, recorded, and analyzed. Data were obtained from 294 patients who met the study's eligibility requirements. The medical records of every patient with a comprehensive medical history were reviewed. The following factors were studied: age, gender, zygomatic arch, maxillary sinus, orbital wall, symphysis of the mandible, parasymphysis, and the condyle. The broken orbital walls in these patients were examined in detail. In the first stage, all of the variables that have been picked will be assessed for their significance from a clinical standpoint. All potential factors contributing to the orbital wall fracture were analyzed using the SPSS and R studio programs. As a result of meeting the inclusion criteria, 294 patients' data has been gathered. Each patient who had a complete medical record was subjected to an examination. In these patients, the cracked orbital walls were examined in greater depth. All chosen variables will be tested in the first stage to see if they are clinically significant. ***Results*****:** The participants in this study were 228 men (77.6%) and 66 women (22.4%). It was found that the most common age ranges are 11-20 years (39.8%), 21-30 years, and 31-40 years (26.2%). According to Spearman correlation, all of the studied variables have a significant accosiation, with a *p*-value of less than 0.05. According to the findings of the multiple logistic regression, it was discovered that gender is significant, [0.2652 (0.1761); $p < 0.25$], Zygomatic Arch fracture, [β_3(SE)= -0.4511(0.2403); $p < 0.25$], Maxillary Sinus, [β_4(SE)= -0.5917 (0.2403) ; $p < 0.25$], Symphysis of the mandible, [β_5(SE)= 2.4826 (0.7298); $p < 0.05$], the condyle of the mandible, [β_5(SE) = 0.9479 (0.4315); exp (0.9479) = 2.58 $\approx$ 3 times], the body of the mandible, [β_5 (SE)= 0.4893 (0.4315) ; $p < 0.25$] and the angle of the mandible, [β_5(SE) = 0.6911 (0.4286); $p < 0.25$]. The validation of the factor through the Multilayer Neural Network (MLNN) and the accuracy obtained 97.71% with the predicted mean square error (PMSE) 0.159%. ***Conclusion:*** The matrix spearman correlation, multiple logistic regression, and neural network uncovered a clear association between orbital wall fracture and several other parameters. This discovery will help researchers understand the most common orbital wall fracture causes in maxillofacial trauma.
Keywords: Fracture, Orbital Wall, Maxillofacial, Spearman Correlation, Multiple Logistic Regression, and Multilayer Neural Network

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1. INTRODUCTION

One of the most common cases that modern hospitals deal with is traumatic injury. Traumatic injury is still a common occurrence on the road, despite various measures such as vehicle safety and advanced technology. An anatomical deformity caused by an uncontrollable force or an acute source of energy coming into direct contact with the body, resulting in the body's inability to tolerate it, is referred to as trauma. Trauma or injury to the maxillofacial region is one of today's most common problems. Oral and maxillofacial trauma can be caused by various factors, including car accidents, animal attacks, war, gunshots or other weapons, sports-related fractures, falls, fights, industrial accidents, and natural disasters. In many countries, motor vehicle accidents are the leading cause of oral and maxillofacial trauma. The event when the facial region is injured, either alone or in combination with other fractures or injuries, including the head region, is referred to as oral-maxillofacial trauma. The face is the most vulnerable area to fracture because it is one of the most exposed parts of our body and has less protection than other organs [4,7]. The prevalence of maxillofacial trauma is considered to differ among the country. According to studies conducted in developed countries such as Singapore, New Zealand, Denmark, Japan, and the Middle East region, motor vehicle accidents are the most common cause of maxillofacial fractures, whereas in less economically developed countries such as parts of Sub-Saharan Africa and South Africa, interpersonal violence such as fights, assaults, and gunshots is the most common cause of maxillofacial fractures [8]. The most common cause of maxillofacial fractures in developed countries like Singapore, New Zealand, Denmark, Japan, and the Middle East is motor vehicle accidents, while in less economically developed countries like Sub-Saharan Africa and South Africa, the most common cause is interpersonal violence like fights, assaults, and shootings [8]. Fractures will vary in severity and type depending on the underlying cause [7]. Traumatic injury, particularly in the maxillofacial region, is still a significant problem for people. It needs to be studied in-depth to find a solution.

In the mid-facial region, fractures of the orbital bone are subtypes that account for up to 40% of all trauma injuries. Intraorbital pressure and force transmission through the bony walls are two common causes of orbital bone injuries. These fractures can be divided into two main categories: those involving the orbital rim and those involving the orbit's interior walls. When the orbital wall and adjoining soft tissue are injured, functional and cosmetic complications such as diplopia, ocular muscle entrapment, and enophthalmos can occur significantly if the fracture diagnosis is delayed [9]. Therefore, the surgical treatment of orbital wall fractures aims to restore the anatomy by reconstructing the fractured orbital walls and reducing the herniated soft tissues. The leading cause of trauma in Malaysia is road traffic accidents. Malaysia is unique compared to other countries because it has different races in the same region, mainly the Malay community, followed by Chinese, Indian, and other ethnic groups [6]. Bone fractures, soft tissue injuries, and dentoalveolar injuries are all types of maxillofacial injuries. These injuries primarily affect men between the ages of 20 and 40, with men in this age group being the most vulnerable. Oral and maxillofacial injuries, like other injuries, can impair a person's ability to perform at a high level [3].

These injuries primarily affect the younger age group, with men between the ages of 20 and 40 being the most vulnerable. Oral and maxillofacial injuries, like other injuries, can impair a person's ability to perform at a high level [3]. Essential functions such as vision, hearing, olfaction, respiration, mastication, and speech occur in the head or face region. Hospital Universiti Sains Malaysia was chosen for this study because it is one of the main government hospitals on Malaysia's east coast, in Kelantan state, covering a demographically significant populated area. Maxillofacial fracture cases are frequently referred from eastern and northern Malaysia states because of the university hospital's excellent facilities and specialists [5]. This study focused on oral maxillofacial trauma and treatment data collected over five years based on a specific pattern. This study establishes a proper correlation between broken or injured orbital walls in patients treated at the Oral Maxillofacial Clinic and Oral Maxillofacial ward, operating theatre Hospital USM in Kelantan, Malaysia.

2. MATERIALS AND METHODS

Medical records from the Oral and Maxillofacial Surgery (OMFS) Unit at Hospital USM Kelantan in Malaysia were reviewed retrospectively from July 2013 to June 2018. Data have obtained from 294 patients who met the inclusion and exclusion criteria using a convenience sample technique. According to the review record, road traffic accidents, fights, assaults, sports, falls, industrial accidents, and others were among the causes of the injuries. Therefore, data were collected under the variables: Seventeen recorded injured sites were included in this analysis. Variables used were gender (coded as sex), zygomatic arch (coded as Szygomaticarch), maxillary sinus (coded as Smaxillarysinus), orbital wall (coded as sorbitalwall), symphysis of the mandible (coded as Ssymphysis), parasymphysis of the mandible (coded as Sparasymphysis), condyle of the mandible (coded as Scondyle), the body of the mandible (coded as Sbodymb), and angle of the mandible (coded as Sanglemb). The Statistical Package for the Social Sciences (IBM SPSS, Chicago, IL,

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USA, software version 26.0) and Rstudio software package was used to conduct the statistical analysis. Three statistical method approaches were combined in this analysis for the best research output.

2.1 Spearman correlation for the orbital wall fracture

The Spearman rank-order correlation coefficient (also known as Spearman's correlation) is a nonparametric measure of the degree and direction of the relationship between two variables assessed on at least an ordinal scale. A Spearman correlation is less sensitive to outliers because it limits the outliers to their rank. A correlation coefficient can range from 1 to a value of +1. + 1.00 = perfect positive correlation, while a -1.00 = perfect negative correlation is defined by the correlation coefficient. There is no correlation between the two variables when their values are 0.00. In other words, the spearman correlation is weak when r_s are between 0.010 and 0.29 or between -0.010 and -0.29, moderate between 0.030 and 0.49 or between -0.30 and -0.49, and strong between 0.050 1.00 or between -0.50 and -1.00 [2].

2.2 Logistics regression for the orbital wall fracture

The logistic regression model for orbital wall fracture (*Y*) status is presented here. The outcome of the variable is orbital wall fracture. The explanatory variables are age(*X1*), gender(*X2*), zygomatic arch(*X3*), maxillary sinus(*X4*), orbital wall(*Y*), symphysis of the mandible (*X5*), parasymphysis of the mandible(*X6*), condyle of the mandible(*X7*), the body of the mandible(*X8*), and angle of the mandible(*X9*). The models are illustrated below.

$$(Orbital\ Wall)_i = \begin{cases} 0, \text{if the orbital wall has a fracture, and the} \\ \text{probability is given as } P\left(Y_i = 0\right) = 1 - \pi_i \\ \\ 1, \text{if the orbital does not having a wall fracture,} \\ \text{and the probabilityis given as } P\left(Y_i = 1\right) = \pi_i \end{cases}$$

This lets us define the following variables.

$$Y_i = E\{Y_i\} + \varepsilon_i$$

Since the distribution of the error term ε_i depends on the Bernoulli distribution of the response Y_i, it is preferable to state the multiple logistics model in the following fashion:

Y_i is independent Bernoulli random variables with expected values $E\{Y_i\} = \pi_i$, where :

$$E\{Y_i\} = \pi_i = \frac{\exp(\boldsymbol{\beta}'\boldsymbol{X})}{1 + \exp(\boldsymbol{\beta}'\boldsymbol{X})}$$

$$E\{Y_i\} = \pi_i = \frac{\exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 +, \ldots, +\beta_9 X_9)}{1 + \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 +, \ldots, +\beta_9 X_9)}$$

The *X* observation is assumed to be a known constant. Alternatively, if the *X* observations are random, $E\{Y_i\}$ it is viewed as a conditional mean, given the value of X_i
This model was fitted by the maximum likelihood method for the 186 cases. The estimate logistic response function is :

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$$E\{Y_i\} = \pi_i = \frac{\exp(\beta_0 + \beta_1(Age) + \beta_2(Gender)+,\ldots,+\beta_9(Angle\_mandible))}{1+\exp(\beta_0 + \beta_1(Age) + \beta_2(Gender)+,\ldots,+\beta_9(Angle\_mandible))}$$

The estimated logit model is given

$$\hat{g}(x) = \beta_0 + \beta_1(Age) + \beta_2(Gender)+,\ldots,+\beta_9(Angle\_mandible)$$

2.3 Modelling MLFF With Two Hidden Layers Approach

Neural networks, also known as artificial neural networks (ANNs), are computer models based on the structure and functionality of biological neural networks. One or more layers can be added between the input, hidden, and output layers to make an MLFF. Only one dependent variable is one output node in the MLFF model. Figure 1 shows the MLFF with N input nodes, H hidden nodes, and a single output node with one hidden node. The values of the hidden node h_j, j =1…3 are given by $h_j = g_1\left(\sum_{j=1}^{3} v_{ji}x_i + E_1\right)$ where v_{ji} the output *weight* E_1 is the bias. The values of the hidden node n_j, j =1…3 are given by $n_j = g_2\left(\sum_{j=1}^{3} v_{ji}h_i + E_2\right)$ where v_{ji} the output *weight.* , E_2 is the bias. The values of the hidden node Y_j, j =1,2 are given by where $Y_i = g_3\left(\sum_{j=1}^{3} v_{ji}n_i + E_3\right)$ v_{ji} the output *weight,* E_3 is the bias. The MLFF's general architecture is as follows:

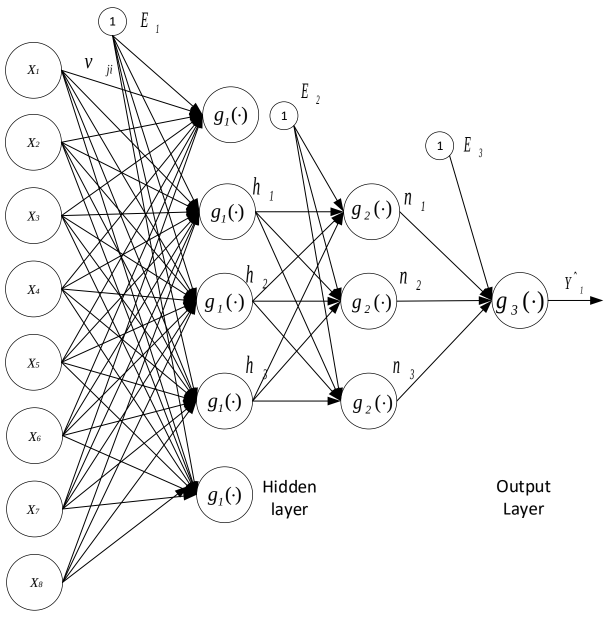

Figure 1: The general architecture of the MLFF proposed in this study.

3. RESULT

In this retrospective study, 294 patients with 196 maxillofacial fractures were included where they met inclusion criteria; out of those, 228(77.6%) were male, and 66 (22.4%) were female. The frequency of patients' ages is shown in Table 1.

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Table 1: Frequency of Patient's Age

	Gender of Patient, *n*(%)	
In years	Male	Female
Less than one years	-	1(0.3%)
1-10 years	7(2.4%)	2(0.7%)
11-20 years	93(31.6%)	24(8.2%)
21-30 years	61(20.7%)	16(5.4%)
31-40 years	29(9.9%)	3(1.0%)
41-50 years	18 (6.1%)	9(3.1%)
More than 50 years	20(6.8%)	11(3.7%)
Total	**228(77.6%)**	**66 (22.4%)**

Table 2: Spearman Correlation Analysis

Site of injury:	1	2	3	4	5	6	7	8	9
1. Orbital wall	1.000	-0.017	0.127*	0.180**	-0.161**	-0.215**	-0.181**	-0.107*	-0.103*
2. Gender of patient		1.000	-0.095	-0.017	0.002	0.082	0.022	0.057	0.054
3. Zygomatic arch			1.000	0.129*	-0.046	-0.109*	-0.058	-0.068	-0.079
4. Maxillary sinus				1.000	-0.086	-0.134*	-0.121*	-0.065	-0.022
5. Symphysis of the mandible					1.000	-0.128*	0.269**	-0.024	0.095
6. Parasymphysis of the mandible						1.000	0.191**	-0.006	0.161**
7. Condyle of the mandible							1.000	0.054	0.018
8. Body of mandible								1.000	0.050
9. Angle of mandible									1.000

Spearman Correlation analysis was applied.

**. Correlation is significant at the 0.05 level (1-tailed).*

Because the data were categorical, descriptive and Spearman correlation analyses were used to determine the correlation strength among the fractured orbital wall. According to Table 2, the orbital wall fracture has a significant association with Zygomatic Arch Fracture (r_s=0.127), Maxillary Sinus Fracture (r_s=0.180**), Symphysis of Mandible Fracture (r_s=-0.161**), parasymphysis of Mandible Fracture (r_s=-0.215**) Condyle of Mandible Fracture (r_s=-0.181**), Body of Mandible Fracture (r_s=-0.107*) and Angle of Mandible Fracture (r_s=-0.103*).

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3.1 Multiple logistic regression

Table 3: Parameter estimates for the multiple logistic regression

Variables (In Code)	Estimate	Std. Error	z-value	*p*-value
(Intercept)	-11.5033	2.1105	-5.450	5.03e-08
Sex	0.2652	0.1761	1.506	0.13196*
Zygomatic arch	-0.4511	0.2583	-1.746	0.08078*
Maxillary sinus	-0.5917	0.2403	-2.462	0.01380*
Symphysis	2.4826	0.7298	3.402	0.00067*
Parasymphysis	1.6834	0.3298	5.104	3.33e-07*
Condyle	0.9479	0.3181	2.980	0.00288*
Body mb	0.4893	0.4315	1.134	0.25682
Angle mb	0.6911	0.4286	1.613	0.10685*

Multiple logistis regeression was applied

** Significant at the level of 0.25*

Table 3 shows the result of multiple logistic regression for the factor related to the orbital wall. According to the findings of the multiple logistic regression, it was discovered that gender is significant, 0.2652 (0.1761), exp = 1.29] women have one time prompt to has to fracture when compared to men, according to the findings of the study. Zygomatic Arch fracture, [β_3 (SE)= -0.4511(0.2583); exp (0.4511) = 0.63, $\approx$36.31%] decreases the odds of fracturing the orbital wall than a patient who does not have a zygomatic arch fracture. Maxillary Sinus, [β_4 (SE)= -0.5917 (0.2403); exp (-0.5917) = 0.5533 $\approx$ 44.7%], has a decrease in the odds the chance of fracturing the orbital wall than a patient who does not have a maxillary sinus fracture. Symphysis of the mandible, [β_5 (SE)= 2.4826 (0.7298); exp (2.4826) = 11.97 $\approx$ 12 times], has 12 times the odd chance of fracturing the orbital wall than a patient who does not have a symphysis fracture. The condyle of the mandible, [β_5 (SE)= 0.9479 (0.4315); exp (0.9479) = 2.58 $\approx$ 3 times], has three times the odd chance of fracturing the orbital wall than a patient who does not have a condyle of mandible fracture. The body of the mandible, [β_5 (SE)= 0.4893 (0.4315); exp (0.9479) = 1.54 $\approx$ 2 times], has two times the odd chance of fracturing the orbital wall than a patient who does not have a body of the mandible fracture. The angle of the mandible, [β_5 (SE)= 0.6911 (0.4286); exp (0.6911) = 2.48 $\approx$ 2 times], has two times the odd chance of fracturing the orbital wall than a patient who does not have an angle of mandible

3.2 Artificial Neural Networks (ANNS): Multilayer Perceptron Model (MLP) for orbital wall fracture

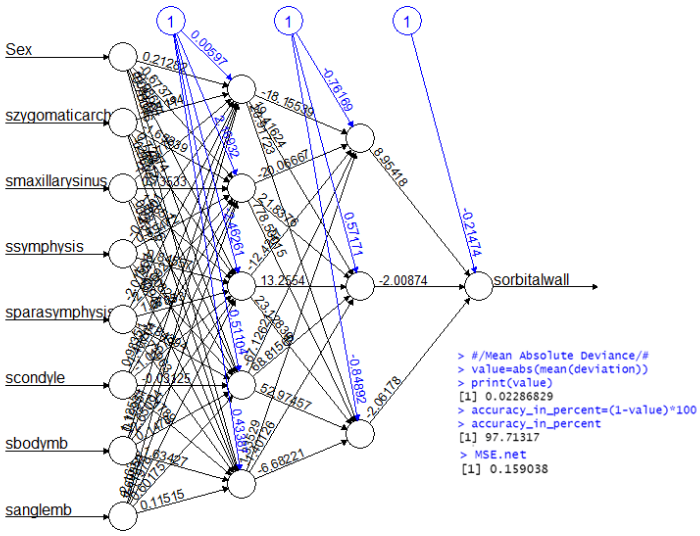

Figure 2: The architecture of the MLP with two hidden layers, eight input nodes, two hidden nodes, and one output node

Table 3 shows the results of multiple logistic regression, and the model's validation is given by Artificial Neural Networks (ANNS) through the multilayer perceptron (MLP). The figure of 0.0229 is the Mean Absolute Deviance (MAD) of the sample. Our predictive data is extensive, and our model forecasts the future with high accuracy is also demonstrated. The value of 0.1590 represents the prediction of the Mean Square Error for the neural network (MSE.net) in terms of mean square error. Figure 2 depicts the complete outcome of the analysis for an MLP with two hidden layers, four input nodes, two hidden nodes, and one output node (with one hidden layer). Based on the data, it has been determined that the analysis is 97.713% accurate.

4. DISCUSSION AND CONCLUSION

According to the study of five years of patient records, men are more likely than women to be exposed to the prevalence of orbital wall fracture, which is about 228(77.6%) compared to women, which is about 66(22.4%). The analysis found that patients between 11-and 20 years old are more exposed to orbital wall fracture 117(39.8%) than other age groups. Meanwhile, patients between the ages of 21 and 30 were the second most vulnerable to orbital wall fracture. This finding was consistent with the study done by [5]. It helps clinicians manage an orbital wall fracture more effectively, and the educators and higher authorities to warn the contributed group about the dangers of driving in the dark. According to the study, the proportion of maxillofacial trauma patients with orbital wall injuries is relatively high among males aged 11-20 years. As a result, this finding will aid in decision-making and benefit the hospital's future actions. Hospital Universiti Sains Malaysia (USM) is a leading teaching hospital in the eastern part of the country; it trains the majority of the country's future specialists; thus, this research examines the specialty's needs and those of the hospital management. Additionally, this Hospital Universiti Sains Malaysia is one of the tops in Malaysia, providing expertise to the eastern part of the country and the entire country. This case study also investigates the most common orbital wall fracture and its relationship to maxillofacial injuries. In this study, the spearman correlation coefficient summarizes the most common fracture associated with the orbital wall from the research perspective. This finding will establish the fundamental understanding of the most common fracture and their association from the theoretically based study.

The second finding shows that, the orbital wall injuries were associated with the five variables, which were Zygomatic Arch Fracture (r_s = 0.127; $p < 0.05$), Maxillary Sinus Fracture (r_s = 0.180**; $p < 0.05$), Symphysis of Mandible Fracture (r_s =-0.161**; $p < 0.05$), Parasymphysis of Mandible Fracture (r_s =-0.215**; $p < 0.05$, Condyle of Mandible Fracture (r_s = -0.181**; $p < 0.05$), Body of Mandible Fracture (r_s = -0.107**; $p < 0.05$) and Angle of Mandible Fracture (r_s = -0.103**; $p < 0.05$). These relationships can be modeled for further research, which could provide vital information to the case specialist and the trained maxillofacial student as part of their curriculum. The third finding also shows that when the orbital wall is injured, the Zygomatic Arch Fracture, Maxillary Sinus Fracture, Symphysis of Mandible Fracture, Parasymphysis of Mandible Fracture, Condyle of Mandible Fracture, Body of Mandible Fracture, and Angle of Mandible Fracture are likely to fracture. The orbit region is anatomically close to the maxilla and zygomatic bone, and this mathematical relationship only emphasizes this fact. This discovery will aid researchers in better understanding the most common fracture in maxillofacial trauma and its causes. Additionally, the findings are critical for future planning, particularly when it comes to preparing for the most frequently used treatment.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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