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### APPLICATION OF LINEAR REGRESSION MODELS TO DETERMINE THE EFFECT OF AGE ON MEASURED ANATOMICAL DISTANCES IN THE TREATMENT OF MANDIBULAR FRACTURES IN CHILDREN

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The study was devoted to the application of linear regression models to determine the effect of age on measured anatomical distances in the treatment of mandibular fractures in children. The study involved 100 cone-beam computed tomography scans of the skull of children aged 6 to 17 years, which were performed due to traumatic injuries, inflammatory diseases, or jaw tumors. Measurements were taken to identify zones on the mandible for screw fixation during open reduction and internal fixation using mini-plates, aiming to prevent trauma to developing tooth buds, roots of permanent teeth, and the mandibular canal. The results indicated that age influences anatomical distances critical for surgical intervention, necessitating age-specific approaches to minimize the risk of complications during the treatment of mandibular fractures in children.

**Key words:** children, data analysis, cone-beam computed tomography, mandible, trauma.

### І.В. Ковач, Г.Е. Зуб, К.П. Локес ВИКОРИСТАННЯ РЕГРЕСІЙНИХ ЛІНІЙНИХ МОДЕЛЕЙ ДЛЯ ВИЗНАЧЕННЯ ВПЛИВУ ВІКУ НА ВИМІРЮВАНІ АНАТОМІЧНІ ВІДСТАНІ ПРИ ЛІКУВАННІ ПЕРЕЛОМІВ НИЖНЬОЇ ЩЕЛЕПИ У ДІТЕЙ

Дослідження було присвячене застосуванню лінійних регресійних моделей для визначення впливу віку на вимірювані анатомічні відстані при лікуванні переломів нижньої щелепи у дітей. У дослідженні використано 100 конусно-променевих комп'ютерних томограм черепа дітей віком від 6 до 17 років, які були виконані внаслідок травматичних ушкоджень, запальних захворювань або новоутворень щелепи. Вимірювання проводили для визначення зон на нижній щелепі для гвинтової фіксації під час відкритої редукції та внутрішньої фіксації за допомогою міні-пластин, щоб запобігти травмуванню зубних зачатків, що розвиваються, коренів постійних зубів і нижньощелепного каналу. Результати вказували на те, що вік впливає на анатомічні відстані, критичні для хірургічного втручання, що зумовлює необхідність вікових підходів для мінімізації ризику ускладнень при лікуванні переломів нижньої щелепи у дітей.

**Ключові слова:** діти, аналіз даних, конусно-променева комп'ютерна томографія, нижня щелепа, травма.

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Starting from the age of six, children become particularly susceptible to traumatic injuries of the facial skeleton. This increased vulnerability is primarily due to their growing involvement in physically active sports and outdoor play, which heightens the risk of such injuries during this developmental stage [6, 7]. Among these injuries, mandibular fractures are the most frequently encountered, with traditional treatment involving bicuspid splinting to stabilize the fracture [2]. However, the management of these fractures becomes more complicated during periods of malocclusion, which may occur due to physiological dental changes such as the transition from primary to permanent teeth, as well as tooth loss resulting from trauma or carious complications. In these cases, bicuspid splinting can prove difficult or even impossible, thus necessitating an alternative approach, such as open reduction and internal fixation using mini-plates [3].

According to current literature, the fixation of mini-plates along the lower edge of the mandible is generally recommended for the treatment of mandibular fractures [12]. However, it is crucial to consider several anatomical and developmental factors specific to pediatric patients. In children, the cortical layer of the jaws is relatively thin and possesses a porous structure due to the presence of a dense network of wide cavernous canals. Additionally, the vascular system of the jaw is of a scattered type, with a significant number of anastomoses between the blood vessels supplying the developing tooth buds and those supplying the jaw itself [3, 11]. This complex vascular architecture increases the risk of vascular injury during surgical procedures.

Moreover, in the bifurcation area of the primary molars, the roots are widely divergent, with their apices situated close to the cortical plate. Since the mineralization of bone tissue in children is not fully complete, these anatomical characteristics create potential challenges for the fixation of mini-plates. When using screws for mini-plate fixation in pediatric patients, there is a substantial risk of inadvertently damaging the developing permanent tooth buds, their roots, or even the mandibular canal, which may lead to long-term complications in dental development and overall jaw function [13].

Thus, in order to prevent complications in the surgical treatment of mandibular fractures during the period of malocclusion, it is necessary to study the anthropometric data of the mandible by conducting linear correlation and regression analyses of the effect of patient age on the measured anatomical distances for open repositioning and internal fixation of mini-plates in childhood.

**The purpose** of the study was to determine the effect of age on the measured anatomical distances in the surgical treatment of mandibular fractures in children of different ages by conducting linear correlation and regression analyses.

**Materials and methods.** The study was conducted on the basis of the department of Maxillofacial Surgery of the Dnipro City Multidisciplinary Clinical Hospital for Mothers and Children named after Professor M.F. Rudnev from 2018 to 2024.

To achieve this goal, we analysed 100 cone-beam computed tomography (CBCT) scans of the skull of children aged 6 to 17 years, which were performed due to traumatic injuries, inflammatory diseases and jaw tumors. CBCT scans were performed on a “Planmeca” computed tomography scanner (2019). All tomograms were taken in somatically healthy children without congenital pathologies.

In all children, we identified zones on the lower jaw, taking into account the anatomical structures for fixation of screws in the treatment of mandibular fractures by the method of open repositioning of internal fixation using mini-plates, and made measurements in millimeters to prevent trauma to the rudiments, roots of permanent teeth and mandibular canal.

The studies were approved by the Biomedical Ethics Committee of Dnipro State Medical University and were conducted in accordance with the written consent of the parents and in accordance with the principles of bioethics set forth in the Declaration of Helsinki “for Ethical Principles for Medical Research Involving Human Subjects” and “Universal Declaration on Bioethics and Human Rights (UNESCO)” [9, 10].

In the case of a normal distribution law, parametric characteristics and analysis methods were used: arithmetic mean (M), standard error (m), standard deviation (SD), coefficient of variation (Cv), 95 % confidence interval for the mean (95 % CI), Student’s test for independent samples (t), taking into account homogeneity/heterogeneity of variances (Fisher’s F test). For data whose distribution differed from the normal one, nonparametric characteristics and criteria were used: median (Me), interquartile range (25 %; 75 %) – 25 and 75 percentiles, respectively Q1 and Q3 – the first and third quartiles), Mann-Whitney U test for comparing two independent samples [1].

Multiple comparisons were made by parametric (ANOVA) and nonparametric (Kruskal-Wallis) analysis of variance, based on the results of which, in the presence of differences, post hoc post-test pairwise comparisons were made by the Tukey test for parametric ANOVA, and by the Dana test for nonparametric ANOVA [5].

To describe the relative values, we used generalising statistical characteristics: relative values (%), 95 % confidence interval (CI), level of statistical significance (p). Confidence intervals for relative values were calculated using the Wald method with normal approximation. The reliability of the differences in nominal variables was assessed using Pearson’s Chi-square ( $\chi^2$ ) criterion, including the Yates correction for continuity for low frequencies and values close to 0 or 100 % [4].

Correlation analysis was conducted with the calculation of Pearson’s linear correlation coefficients (r) and Spearman’s rank correlation ( $r_s$ ) in accordance with the conditions of their application, as well as linear regression analysis with the calculation of partial correlation coefficients. In the absence of a normal distribution in quantitative data, the Box-Cox transformation of these primary data was performed to obtain a normal distribution of the variables to be analysed [8].

Statistical processing of the research results was carried out using descriptive and analytical biostatistics methods implemented in the software packages STATISTICA 6.1 (StatSoftInc., serial number AGAR909E415822FA) and Microsoft Excel (Office Home Business 2KB4Y-6H9DB-BM47K-749PV-PG3KT). The critical value of the level of statistical significance ( $p$ ) for all types of analysis was taken as  $<5\%$  ( $p < 0.05$ ) [4].

**Results of the study and their discussion.** To perform linear correlation and regression analyses, taking into account the fact that the distribution of some quantitative characteristics did not follow the normal law, the primary data were transformed using the Box-Cox method. Further correlation analysis (Table 1) showed the presence of certain regularities in the correlation between the age of the subjects and the measured anatomical dentoalveolar distances.

Table 1

**Correlations between the age of the subjects and the measured anatomical dentoalveolar distances**

Relationship between age and indices	Pearson's correlation coefficients ( $r$ )	
	$r$	$p$
Age group 6–11 years old		
Shortest distance from the lower margin of the mandible to the root tips of the first permanent incisors (mm)	0.01	0.953
Shortest distance from the lower margin of the mandible to the root tips of the second permanent incisors (mm)	-0.01	0.885
Shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level of the distal root of the first permanent molar (mm)	0.11	0.258
Shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar (mm)	0.21	0.036
The shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar and the second premolar (mm)	0.15	0.127
Shortest distance from the buccal margin of the middle third of the mandible body to the distal root of the first permanent molar (mm)	-0.14	0.172
Age group 12–17 years old		
Shortest distance from the lower margin of the mandible to the root tips of the first permanent incisors (mm)	0.03	0.75
Shortest distance from the lower margin of the mandible to the root tips of the second permanent incisors (mm)	0.08	0.457
Shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level of the mesial root of the first permanent molar (mm)	0.02	0.858
Shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level of the distal root of the first permanent molar (mm)	0.1	0.342
Shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar (mm)	0.1	0.333
The shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar and the second premolar (mm)	-0.07	0.465
Shortest distance from the buccal margin of the external oblique line of the mandible to the second permanent molar (mm)	-0.19	0.059

The presence of statistically significant correlations was determined in the age group of 6–11 years, none in the 12–17 years group, which may be explained by the influence of other factors and anatomical and physiological features in this age group.

The linear correlation coefficients indicate a direct correlation between age and the shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar in the group of children aged 6–11 years ( $r=0.58$ ;  $p < 0.001$ ).

Regression analysis was performed to analyze the relationships and to determine models for predicting anatomical distances for intervention in the treatment of mandibular fractures in children with variables that had statistically significant correlations with age. The age of the subjects was considered as a predictor (factor) variable –  $x$ , and the measured anatomical distances were used as dependent (resultant) variables ( $y$ ).

We conducted a regression analysis with the construction of simple (paired) linear regression models. The mathematical equation describing the simple linear regression line has the following general form:

$$y = a + b \times x, \text{ where}$$

$x$  – an independent variable (predictor), in our case, the age of the examined patients;

$y$  – is the dependent variable, in our case the measured anatomical distances (in mm). This is the value we expect for  $y$  (on average) if we know the value of  $x$ ;

a – is a constant, a free term of the equation (the value of y when x=0);  
 b – regression coefficient (tangent of the slope of the regression line to the X-axis).

The results of the regression analysis in cases where statistically significant results were obtained are presented in Table 2 and Figure 1. The identified models include the free terms of the equation, as they have a statistically significant level ( $p < 0.05$ ).

Table 2

**The results of a simple linear regression analysis of the influence of the age of the subjects on the values of anatomical distances used for intervention in the treatment of mandibular fractures in children**

Indices	b*	Error b*	b	Standard error b	t	p
The influence of age on the shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar in children aged 6–11 years						
The free term of the equation	–	–	1.907	1.710	1.115	0.027
Age	0.210	0.099	0.427	0.201	2.125	0.036
Equation	$y = 1.907 + 0.427 \times x$					
Overall assessment of the model	Multiple correlation coefficient $R = 0.581$ ; coefficient of determination $R^2 = 0.338$ , adjusted $R^2 = 0.331$ Fisher's criterion $F = 49.986$ ( $p < 0.001$ )					

Note. b – ordinary regression coefficients; b\* – standardised regression coefficients; t – coefficient criterion of the regression equation; p – statistical significance level.

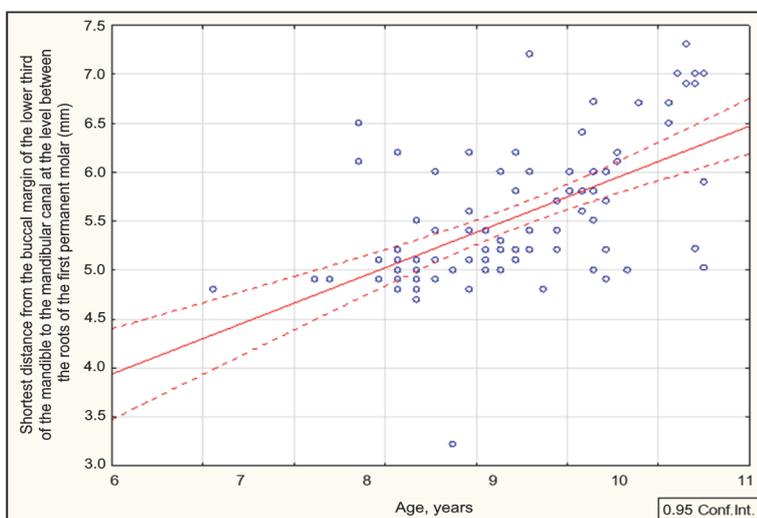


Fig. 1. Dependence of the shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar on age in children aged 6–11 years.

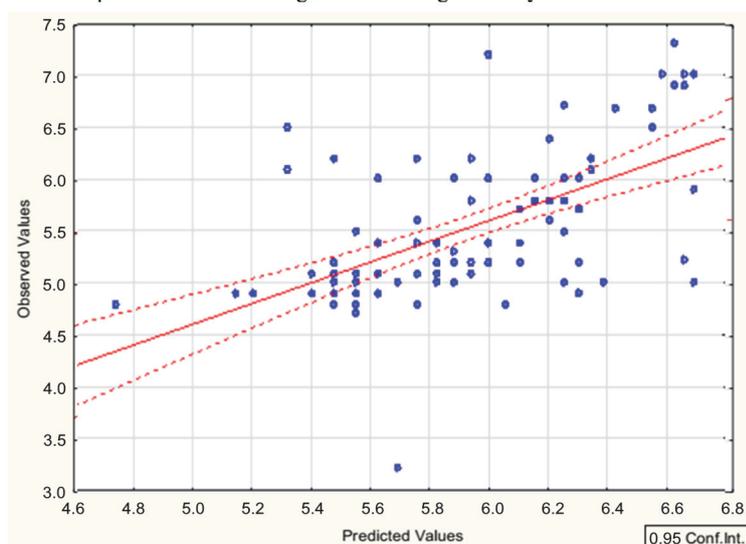


Fig. 2. Scatter diagram between the predicted and observed values of the dependent variable (the shortest distance from the buccal margin of the lower third of the lower jaw to the mandibular canal at the level between the roots of the first permanent molar in children aged 6–11 years) according to the linear regression equation depending on age (95 % confidence interval).

Thus, the quantitative assessment of the influence of age on the shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar in children aged 6–11 years can be described by the equation:

$$y = 1.907 + 0.427 \times x, \text{ where}$$

y – the shortest distance from the buccal margin of the lower third of the lower jaw to the mandibular canal at the level between the roots of the first permanent molar in children aged 6–11 years;

x – age of the examined children.

According to the obtained regression model, the coefficient of determination is  $R^2 = 0.338$ , adjusted  $R^2 = 0.331$ , so the variability (fluctuation) of the shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar in children aged 6–11 years is 33.1 % due to the influence of children's age. The partial correlation coefficient (cleared from the influence of other factors) indicates a direct medium strength correlation between the variables ( $r = 0.58$ ;  $p < 0.001$ ).

The validity of the regression equation was tested using Fisher's F test, with the results of the study showing  $F = 49.986$  ( $p < 0.001$ ).

The standard errors of the model parameter estimates show that, on average, the values of anatomical distances calculated by the equation deviate insignificantly from the actual ones, which is confirmed by the scatter plot between the predicted and actual values of the dependent variable (Fig. 2).

This study quantified the effect of age on specific anatomical distances important for the surgical treatment of mandibular fractures in children. A significant direct correlation was found between age and the shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar in children aged 6–11 years. This indicates that as children grow within this age group, this anatomical distance increases, which is crucial for surgical planning to minimize the risk of damaging vital structures during fixation. These findings are consistent with previous studies emphasizing the unique anatomical considerations in pediatric patients due to ongoing growth and development [6]. The increase in mandibular dimensions with age affects the positioning of anatomical landmarks, impacting the approach to open reduction and internal fixation using mini-plates. Precise knowledge of these anatomical changes can aid in optimizing fixation methods and reducing complications, as highlighted in other research [7]. Our study provides quantitative data that enhance surgical planning by allowing clinicians to anticipate changes in anatomical distances based on patient age. Challenges in treating mandibular fractures during the mixed dentition period have been noted, underscoring the need for age-specific approaches [2]. By incorporating regression analysis, we offer a predictive model that assists surgeons in selecting appropriate fixation points for mini-plates, thereby reducing the risk of injuring developing tooth buds or the mandibular canal. Understanding pediatric mandibular anatomy is crucial for surgical interventions [3]. Our findings contribute to this understanding by providing measurable changes in anatomical distances with age, informing the development of surgical guidelines tailored to pediatric patients. Individualized treatment plans are essential due to variability in facial growth and development [12]. Our regression model supports personalized care by allowing estimation of anatomical distances based on the child's age, enhancing the safety and efficacy of surgical treatments. Further studies with larger and more diverse pediatric populations are necessary to validate and refine the regression models developed. Longitudinal research could provide deeper insights into individual growth patterns affecting mandibular anatomy. Incorporating advanced imaging techniques may enhance the precision of anatomical measurements, ultimately improving surgical outcomes for children with mandibular fractures.

## Conclusions

1. Based on the analysis of anthropometric characteristics from cone-beam computed tomography scans of children during the mixed dentition period, we identified possible variants of fracture lines and developed recommendations for the fixation of mini-plates.
2. These recommendations were confirmed through linear correlation and regression analyses, which demonstrated that the anatomical distances calculated using the regression equation deviated insignificantly from the actual measurements.
3. This is further supported by the scatter plot between the predicted and observed values of the dependent variable, indicating that the fluctuation in the shortest distance from the buccal margin of the lower third of the mandible to the mandibular canal at the level between the roots of the first permanent molar in children aged 6–11 years is 33.1 % due to the influence of the children's age.

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### USING A SOFTWARE PACKAGE FOR PREDICTING THE STATE OF THE INTERDENTAL GINGIVAL PAPILLA IN PATIENTS WITH GENERALIZED PERIODONTITIS AFTER RESTORATION OF THE CONTACT SURFACES OF THE POSTERIOR TEETH

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The study was devoted to the analysis the possibilities of a software product to determine the probability of preserving or restoring interdental gingival papillae depending on the parameters of the elements of the interdental triangle during the direct restoration of caries-affected contact surfaces of the posterior teeth in patients with generalised periodontitis of the initial and initial-I degree of severity. The clinical trial involved 150 patients aged 18 to 45 years. To predict the likelihood of preserving or restoring interdental papillae during the restoration of the contact surfaces of the posterior teeth in patients with generalised periodontitis, the Papillary Expert software product was developed and clinically tested. The developed software provided a high level of accuracy in predicting the preservation or restoration of interdental gingival papillae after restoration of the contact surfaces of posterior teeth in patients with generalized periodontitis, thereby aiding in selecting the most effective treatment strategies.

**Key words:** caries, treatment, contact surfaces, generalized periodontitis, programming.

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### ВИКОРИСТАННЯ ПРОГРАМНОГО ЗАБЕЗПЕЧЕННЯ ДЛЯ ПРОГНОЗУВАННЯ СТАНУ

### МІЖЗУБНИХ ЯСЕННИХ СОСОЧКІВ У ПАЦІЄНТІВ З ГЕНЕРАЛІЗОВАНИМ

### ПАРОДОНТИТОМ ПІСЛЯ ВІДНОВЛЕННЯ КОНТАКТНИХ ПОВЕРХОНЬ ЗАДНІХ ЗУБІВ

Дослідження було присвячено аналізу можливостей програмного продукту для визначення ймовірності збереження або відновлення міжзубних ясенних сосочків залежно від параметрів елементів міжзубного трикутника при прямій реставрації уражених каріесом контактних поверхонь бічних зубів у пацієнтів з генералізованим пародонтизом початкового та початкового-I ступеня тяжкості. У клінічному дослідженні взяли участь 150 пацієнтів віком від 18 до 45 років. Для прогнозування ймовірності збереження або відновлення міжзубних сосочків при реставрації контактних поверхонь бічних зубів у пацієнтів з генералізованим пародонтизом був розроблений і клінічно апробований програмний продукт «Papillary Expert». Розроблене програмне забезпечення забезпечило високий рівень точності прогнозування збереження або відновлення міжзубних ясенних сосочків після реставрації контактних поверхонь бічних зубів у пацієнтів з генералізованим пародонтизом, тим самим допомагаючи у виборі найбільш ефективних стратегій лікування.

**Ключові слова:** карієс, лікування, контактні поверхні, генералізований пародонтизм, програмування.

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In modern medical practice, information technologies are increasingly used, which are now becoming an integral part of the work of a dentist of any specialty. The assessment of dental status using digital photography, according to 3D examination data in combination with computer image analysis technology is innovative and is intensively developing as a direction of the medical and diagnostic process [2].

A condition for the normal functioning of any body system is the perfection of its morphological and functional relationships [5]. One of the leading criteria for the successful treatment of caries of the contact surfaces of the posterior teeth in patients with generalized periodontitis is the preservation or restoration of the interdental gingival papilla, and this is possible provided that certain relationships are maintained between the components of the periodontal complex with the obligatory preservation of each