The Creation of Mandible Geometrical Model by Application of Synthetic Intellect Method

Karim Najm. Husain

Mechanical Department, Faculty of Engineering, Al-Qadisiyah University, R. of Iraq
karim.husain@qu.edu.iq

ABSTRACT

Applying custom implants to treat bone fractures for each patient is the best treatment currently, and it represents the contemporary medical trend in the field of treating human bone fractures(Mandible). In order to design custom implants, we must provide a 3D barometric model that is compatible with a specific patient. The model of points is applied by utilizing a method of anatomical entities that form polygonal shapes and multiple regression to create a standard three-dimensional model of the mandible bone.

For the purpose of obtaining good accuracy in predicting the parameters, mathematical calculations are formed for the parameters that represent the dimensions that can be obtained from medical images (CT,MRI) and the anatomical trends that are taken from the coordinates of the measured points and the implementation of the synthetic intelligence method in the approach of creating a three-dimensional model of the mandible bone, as well as applying the analysis of The deviation to know and determine the geometric accuracy of the barometric model that has been worked on, and the result of analysis which performed between the resulting model and the initial model was satisfactory, which was done through the use of CAD and CATIA software.

Keywords: Custom Implants, Anatomical Entities, Geometric, Model, Deviation

1.Introduction

Depending on the analysis of medical images of the mandible bone, an engineering model is created and developed, and the mandible model is simulated, as well as the scaffold and the external and internal fixation tools used. For the purpose of the definition between the three-dimensional geometric models that were created for the mandible in cases where it is not possible to obtain sufficient information through the images on the basis of which the geometric model was formed. The use of the application of the CT or MRI image, which can be employed in research related to the medical field that depends on computer applications, use of these images provides the possibility to allow data and information processing where can obtain information about the anatomical structure of the mandible [1,2,3].

It is very difficult to create a three-dimensional geometrical model of the mandible based on the use of traditional approach, especially if we know that the mandible has a very complex geometry in addition to the great lack of information available about the topography and shape of the mandible surface and its complex geometry. However, reverse engineering depends a lot on the accuracy of the images as a result, the accuracy of the geometric model is based on the accuracy of the cross-sectional medical images that were used in inverse modeling [4,5]. Sometimes it is difficult to obtain accurate and complete medical images of the mandible because it may suffer from congenital malformations or diseases such as cancer, fragility, and necrosis. Also, the location of the mandible at the bottom of the face makes it vulnerable to fractures due to falls or various accidents. In this case, the information obtained from the cross-sectional images is incorrect and inaccurate and thus affect the accuracy of the obtained geometric model. Accordingly, the mirror imaging method must be applied, which is one of the possible solutions for rebuilding lost or damaged anatomical structures, depending on determining the morphological changes that occurred to the mandible and its shape [6,7,8]. The adoption of statistical models is one of the possible solutions that can be applied to reconstruct a three-dimensional geometric model of a complete mandible bone that depends on the prediction of this model without the possibility of determining the accuracy of the prediction of the model's geometry and shape away from the input data [9,10]. The purpose of research is to apply the method of anatomical features, which was successfully used to create a complete barometric model of mandible using reverse engineering and compared it with statistical methods and applied it in the field of artificial intelligence to reach the highest possible accuracy in the model prediction process. The purpose of research is to apply the method of anatomical features, which was successfully used to create a complete barometric model of mandible using reverse engineering and compared it with statistical methods [11,12,]. The purpose of applying MAF in the field of artificial intelligence is to reach the highest possible accuracy in the model prediction process.

2. The Materials And Method

Depending on tomography images of the mandible and engineering analysis of the data of sixteen CT images of a Without bone diseases adult women mandible acquired from the Toshiba MSCT Aquillion scanner depending on standard flow) [13] and application of the MAF to create a 3D parametrical model of the mandible. The procedures for forming a parametrical model are clarified in Figure 1.

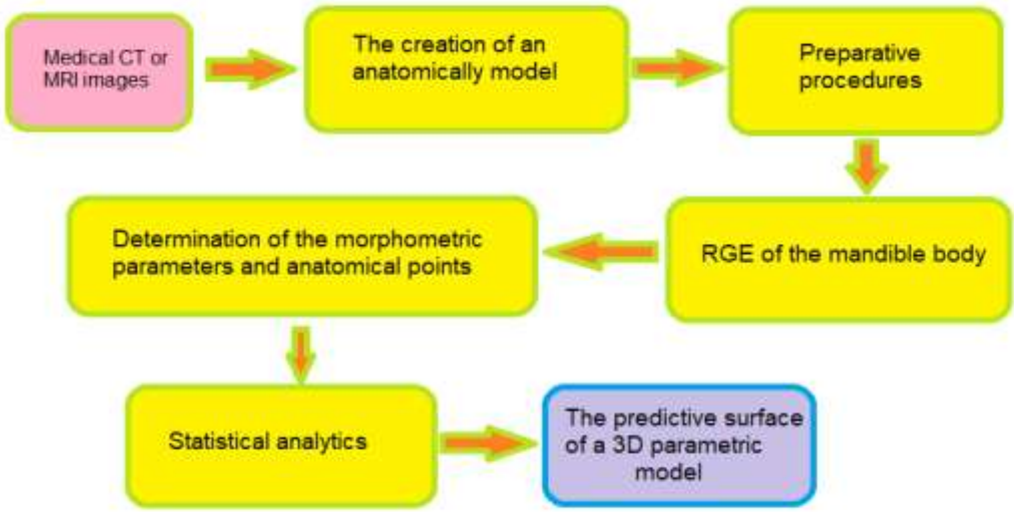

Figure 1. Schematic of procedures of creation of a 3D parametric model

For the purpose to form a polygonal model with high accuracy, cleaning (cutting out bumps, growths, tumors, and other defects if any), patching holes, missing parts, and healing the cloud of obtained points were performed. This is done after hashing and converting the CT data obtained to the proper format (STL) file with the application of CATIA software.

3.Mandible Referential Geometrical Entities (Rges)

The reference geometric entities are lines, axes, planes, and points which are used in the best potential way to construct geometrical entities that convergent the topology and geometry of the mandible model. Morphometrically analyses were implemented for all polygonal models for the purpose to specify reference geometric entities and anatomically orientations. Figure 2 shows distinctive anatomically points specified in the polygonal model and planes of the coordinate system [15,14].

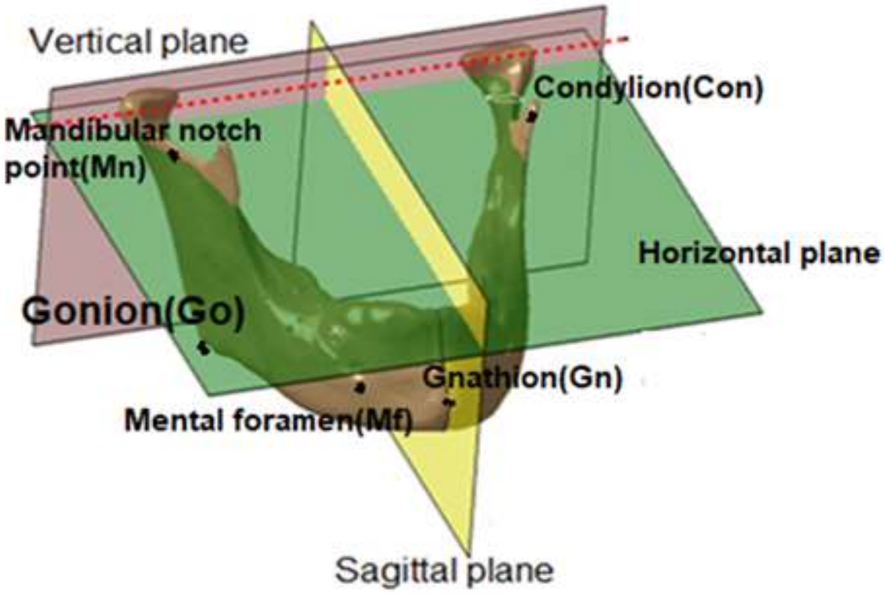

Figure 2. The referential geometrical entities of the mandible

4. The Anatomical Points And Morphometric Parameters

10 central and binary morphometric parameters can be determined using distinct anatomical points that depict the build of the mandible bone depending on anatomical, and the morphological characteristics of mandible bone. There is displayed a detailed definition [16]. The morphological parameters are present in Fig. 3. We must illustrate that the geometric model of the mandible is the parametric model that was created from the cloud points, and every point in this cloud can be determined through the function of the parameter.

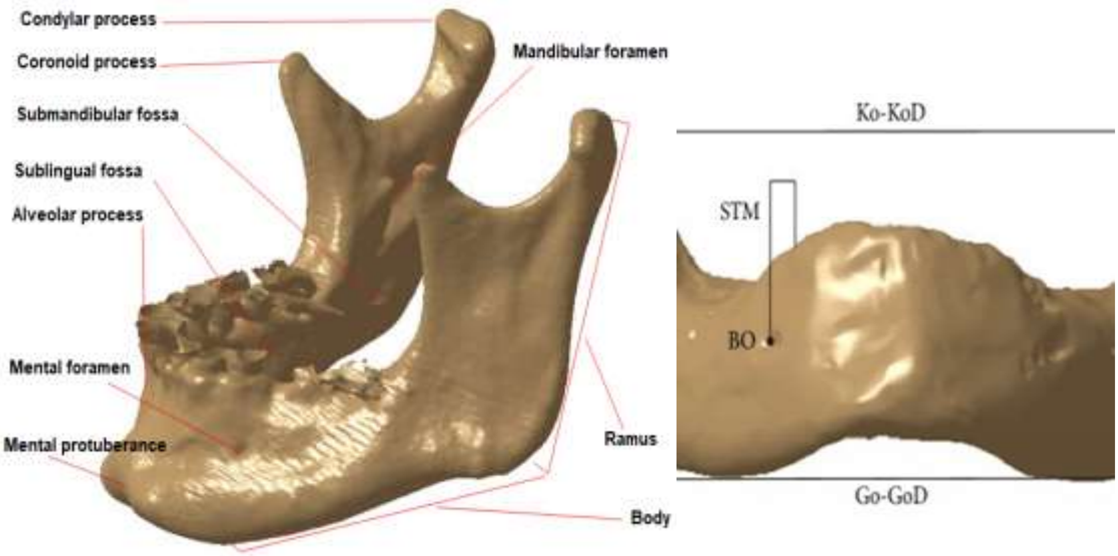

Figure 3. Morphometry's parameters

After the coordinate system has been determined, we can get the values of the coordinates of the anatomical points, which can be measured in the polygonal model. 56 anatomically points created on the spline curve created by the multi sections of the mandible body and they represent the input data for the statistical analysis shown in fig.4.

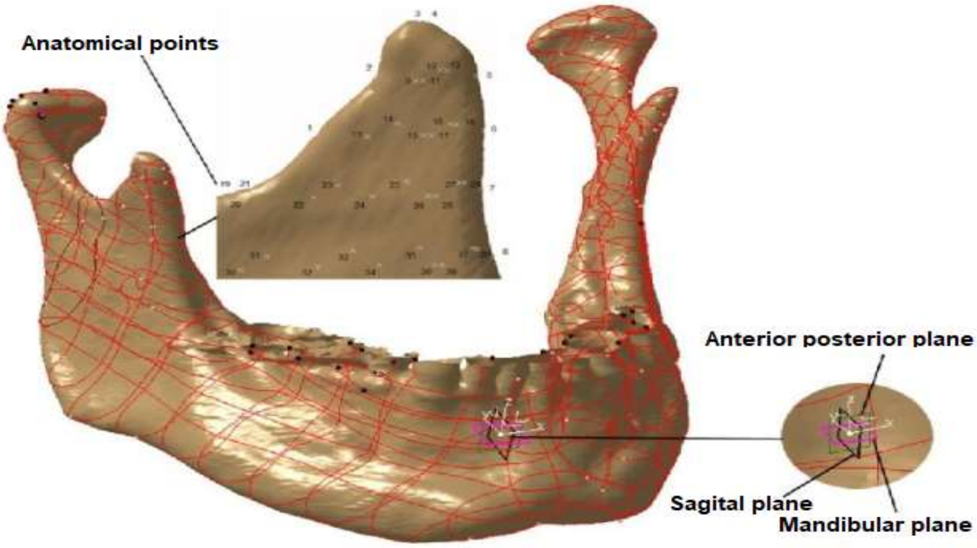

Figure 4. The anatomical points on the mandible polygonal model

5. The Statistical Analysis

In order to form a computational form (a mathematical equation) that represents the connection between the input and output of the variables' data. MAF was employed to achieve this purpose (the relationship) using multiple regression analysis and the development of this mathematical model by applying the measure of values of the formal parameters as input data and the measure of values of the coordinates of the anatomical points as output data. The mathematical equation of regression will be in the following form.

$$C = \beta_0 + \beta_1 C_1 + \beta_2 C_2 + \beta_3 C_3 + \ldots + \beta_p C_p + \varepsilon$$

where:

β -parameters for evaluation

ε - measurement of error

C - dependent variable, and

C1-p - the gauged values of morphometric parameters in each specimen.

The analysis of the effect of variable parameters on the precision of the mathematical model was conducted to maintain data quality and at the same time reduce the number of parametric parameters.

For the mathematical model, the C_1 and C_4 separated variables have high values of correlation coefficients and thus led to the deletion of the variable C4[17,18].

The type of mandible mathematical model, its complexity, and the chosen function is impact the quality and precision of the mathematical model. The development of the mathematical model and the mathematical equation depends on parametric modeling [19]. On the basis of the chosen function, the multiple retraction (regression) analysis gives a statistical valuation of the mandible mathematical model.

In this case, we can estimate the solutions that were getting by this model were within the values of the range of the congruent variables, and the mathematical model is suitable. Based on this, the process of creating a parametric model from a considerable number of input data necessitates the need for very complex mathematical models, which leads to more prediction precision.

6. Prediction Development

The application of artificial intelligence techniques is one of the most important alternatives used successfully in the process of creating a mathematical model.

To implement precise connections, must define the input and output variables by using synthetic neural networks, which are considered the most common in this field, as their neurons are linked by likely links, where the knowledge that the networks possess is preserved.

The neural network model shows the measured values of the parameters data as input data and the coordinate values as output data, illustrated in Figure 5. The statistical analysis that was carried out identified a set of input and output data and a set of basics that are utilized in training for the synthetic neural networks (synthetic neural networks). In this research, values of the morphometric parameters represent the input data, While the output values can be represented by measuring the coordinates of the anatomical points represents as examples, that were offered to the network in order to gain more knowledge. Before conducting the training process, one must reduce the range of input and output data values, and this is done by conducting a preprocessing for the purpose of ensuring the stability of the network and the absence of instability in it. In this paper, the data is normalized within the form 0 to1 to -1 standard range, and the wished input and output data is normalized within 0 to 1 range identical to the sigmoid transport function and its function is neutralized in an output layer and invisible layer. The use of the trial/error method is the most important way to choose the number of the number invisible layers (architectural parameters) and invisible neurons

The backpropagation (BP) algorithm can also be used to develop the synthetic neural networks model. When there is no more decrease in the error between result values and the expected output values, the training network is stopped. For the purpose of evaluating the prediction accuracy of the SNN model by applying the mean of the summation of the squared error is applied.

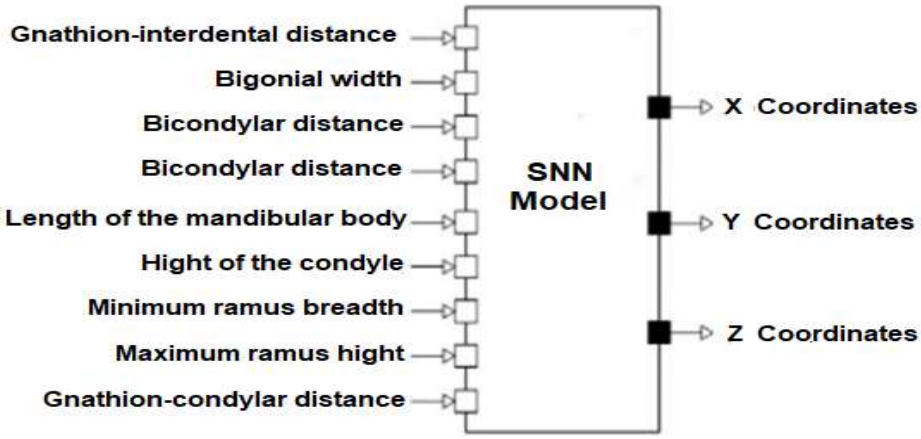

Figure 5. The synthetic neural networks(SNN) model with input and output data

7. The Prediction Development

Table 1 presents a summary of the architectural and training parameters of the SNN model, that is used to develop the SNN model after the performed of triangles procedures in Matlab was executed in the process of documenting the coordinates of anatomic points by executing the training for the SNN models.Table 1: SNN parameters for the training

1	No. Of hidden neurons	45
2	No. Of input neurons	9
3	No. Of output neurons	3
4	The algorithm	BP
5	The momentum	0.615
6	MSE	0.001
7	No. Of training periods	1462
8	Transfer functions in the hidden layer	logsig
9	Transfer functions in output layer	logsig

Table 2 present the SNN model statistical errors and the use of a further statistical criterion, which is the disparity between the measured and anticipated (predicted) values, for the purpose of the increasing accuracy of capability in estimating the anticipation(prediction) of the developed model of the SNN

Table 2: The performance of the SNN model

Subject	**MSE**		**Deviation (mm)**		
SNN	The training set	Testing data set	**X**	**Y**	**Z**
1	0.001	0.026	0.294	0.255	0.387

Table 3 presents the results of the analysis that was carried out on the resultant surface model. which was formed using SNN (row No.1), and the resultant surface model that was previously built using multiple regression (row No.2). This represents the implementation of the geometric accuracy test of the models obtained by applying the perversion analysis between the input and the resultant models in the CATIA pr

Table 3: Comparing the achieved values of the deviation of the sample

Analysis of deviations (mm)		
Sample No.	The sample created by SNN	Sample created by multiple regression
1	**0.39**	1.04
2	0.32	1.54
3	0.34	**2.39**
4	0.37	2.08
5	**0.39**	1.96
6	0.37	1.73
7	0.32	2.05
8	0.34	1.63
9	0.33	1.72
10	**0.39**	1.64
11	0.35	1.96
12	0.36	1.74
13	0.34	1.o7
14	0.35	2.12
15	0.34	1.66
16	0.24	2.58

The results of the deviation analysis presents in Table 3 , and it is clear that the maximum value of the deviation is 0.39 for the models that were constructed using the SNN, While the maximum value of the deviation is 2.39 for the models that were built by multiple regression. Depending on these results were presented in Table 3, which were obtained by applying the comparative analysis of the deviation values of the models created depending on SNN and the models that were created depending on the multiple regression.

Based on the results that have been reached in this paper, the method of prediction presented in this research is a new prediction promising method. Figure 6 shows the maximum deviations of the model of the mandibular surface created based on SNN model.

Analysis of deviation	
Points	Proportion
3980	100.00 %
Subject	Value (mm)
Max. positive deviation	0.116
Mean positive deviation	0.0164
Max. negative deviation	- 0.298
Mean negative deviation	- 0.00188
Mean deviation	- 0.00569

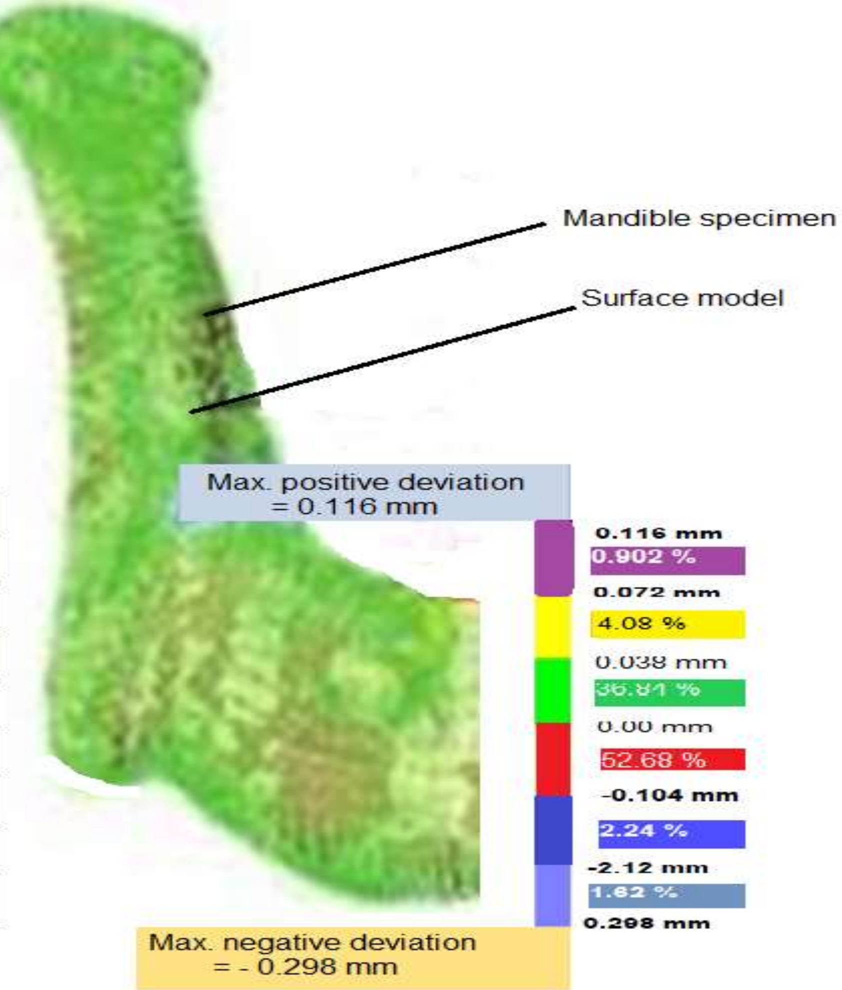

Figure 6. The extremum mandible surface model deviations from the input SNN model

8. Conclusion

The application of the improved and developed approach showed the need for more research in the field of an accurate analysis of the morphologic characteristics of the geometric model of the mandible that was created and the usage of another mathematical models to reach a more accurate model. The model creates on the basis of SNN has an accuracy that qualifies it for the applications of implant and osteofixation design, preoperative planning, surgical simulation, postoperative and recovery applications. The development of a modeling approach to bone geometry (mandible) constitutes an important contribution to improving the anatomical and geometric accuracy of the model.

References

1. H. Lamecker, S.Zachow, A. Wittmers, B. Weber, H. Hege, B. Elsholtz and M. Stiller, "Automatic Segmentation of Mandibles in Low-Dose CT-Data", Int. J. Comput. Assist. Radiol. Surg, Vol. 1(1), pp. 393–395, (2006)
2. Nikola Vitković, Jelena Mitić, Miodrag Manić,1Miroslav Trajanović, Karim Husain,Slađana Petrović, and Stojanka Arsić,The Parametric Model of the Human Mandible Coronoid Process Created by Method of Anatomical Features,Hindawi, Computational and Mathematical Methods in Medicine , https://doi.org/10.1155/2015/574132
3. M.Lipski, I.M. Tomaszewska, W. Lipska, G.J. Lis4, K.A. Tomaszewski. The mandible and its foramen: anatomy, anthropology, embryology, and resulting clinical implications. Folia Morphol. Vol. 72, No. 4, pp. 285–292.DOI: 10.5603/FM.2013.0048, Copyright ©

2013 Via Medica,ISSN 0015–5659.www.fm.viamedica.pl.

4. Jayanthi Parthasarathy,3D modeling, custom implants and its future perspectives in craniofacial surgery. Ann Maxillofac Surg. 2014 Jan-Jun; 4(1): 9–18., doi: 10.4103/2231-0746.133065..
5. Karim Najm Husain, Mohammed Rashid and Nabeel Almuramady,Novel Procedural Modeling of 3d Model of Tibia Bone Scaffold by Implementation of Method Anatomical Features, Journal of Optoelectronics Laser, ISSN 1005-0086, volume 41 issue 4,2022 , http://www.gdzjg.org/index.php/JOL/index.
6. Jelena Milovanovic,Milos Stojkovic, Karim Najm Husain , Jovan Arandjelovic, Holistic Approach in Designing the Personalized Bone Scaffold: The Case of Reconstruction of Large Missing Piece of Mandible Caused by Congenital Anatomic Anomaly, HindawiJournal of Healthcare EngineeringVolume 2020, Article ID 6689961, 13 pageshttps://doi.org/10.1155/2020/6689961
7. J. Watson, M. Hatamleh, A. Alwahadni and D. Srinivasan, "Correction of Facial and Mandibular Asymmetry Using a computer aided design/computer aided manufacturing Prefabricated Titanium Implant", J.Craniofac. Surg., Vol.25 (3), pp. 1563, (2014)
8. Laszlo Series, Endre Varga Jr, Andras Kocsis, Zoltan Rasko, Balazs Bago, Endre Varga & Jozsef Piffko, Correction of a severe facial asymmetry with computerized planning and with the use of a rapid-prototyped surgical template: a case report/technique article, Head Face Med 10, 27 (2014). https://doi.org/10.1186/1746-160X-10-27
9. Karim Najm HUSAIN, Miloš STOJKOVIĆ, Nikola VITKOVIĆ, Jelena MILOVANOVIĆ, Miroslav TRAJANOVIĆ, Mohammed RASHID, Aleksa MILOVANOVIĆ, Procedure for Creating Personalized Geometrical Models of the Human Mandible and corresponding Implants,Technical Gazette 26, 4(2019), 1044-1051https://doi.org/10.17559/TV-20181009193111
10. S. Benazzi, E. Stansfield, O. Kullmer, L. Fiorenza andG. Gruppioni, "Geometric morphometric methods for bone reconstruction: the mandibular condylar process of Pico della Mirandola", Anat. Rec., Vol. 292(8), pp. 1088–1097, (2009)
11. S.G. Kim, W.J. Yi, S.J. Hwang, S.C. Chio, S.S Lee and M. S. Heo, "Development of 3D statistical mandible models for cephalometric measurements", Imaging Sci. Dent., Vol. 42 (3), pp. 175-182 (2012)
12. C.Klop & MAGIC Amsterdam,A three-dimensional statistical shape model of the growing mandible, MAGIC Amsterdam (2021). Scientific Reports, 11(1), [18843]. https://doi.org/10.1038/s41598-021-98421-x
13. Harald Essig, Majeed Rana, Horst Kokemueller, Constantin von See, Martin Ruecker, Frank Tavassol, and Nils-Claudius Gellrich, Pre-operative planning for mandibular reconstruction - A full digital planning workflow resulting in a patient specific reconstruction, Head Neck Oncol. 2011 Oct 3.doi:10.1186/1758-3284-3-45,
14. O. KENYANYA, M. L. CHINDIA, J. HASSAN ALI, and G. P. POKHARIYAL, MORPHOMETRIC PARAMETERS OF KENYAN ADULT MANDIBLES, East African Medical Journal Vol. 88 No. 10 October 2011
15. Ditty J Mary and Karthik Ganesh Mohanraj, Morphological and Morphometric Analysis of Mandibular Foramen and Lingula with Reference to Gonial Angle in Dry Human Mandibles, Journal of Research in Medical and Dental Science,eISSN No. 2347-2367 ISSN No. 2347-2545
16. Suciu Mircea,Cazacu Razvan,Grigoras Radu Ionut,Bica Cristina Ioana, Parametric modeling of the human mandible lateral body for the shape

optimization of its section in the case of bone augmentation, procedia technology 19(2015)934-941

17. Karim Husain, Mohammed Rashid, Nikola Vitković, Jelena Mitić, Jelena Milovanović, Miloš Stojković., GEOMETRICAL MODELS OF MANDIBLE FRACTURE AND PLATE IMPLANT, FACTA UNIVERSITATIS .Series: Mechanical Engineering DOI: 10.22190/FUME170710028H
18. M. Madić and M. Radovanović, "Methodology of developing optimal BP-ANN model for the prediction of cutting force in turning using early stopping method", F. U.Mech. Eng., Vol. 9(1), pp. 21-32, (2011).
19. Nabeel Almuramadya, Feodor M. Borodicha, Irina G. Goryachevac, Elena V. Torskayac, Damage of functionalized self-assembly monomolecular layers applied to silicon micro gear MEMS, Elsevier, Tribology International Volume 129, January 2019, Pages 202-213