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AN ANALYSIS OF THE DURABILITY OF THE MANDIBLE ANGLE OSTEOTOMY FOR VARIOUS CASES OF OSTEOSYNTHESIS

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ABSTRACT: *The mandible performs a complicated function in the human body. Several factors, such as the osteogenesis in childhood and adolescence and the properly formed temporomandibular joint and occlusion, have a bearing on the proper functioning of the mandible. The restoration of the normal physiological functions through a mandible fracture treatment is a multi-faceted process which is difficult from the point of view of both the doctor and the patient. All this indicates the complexity of the use of implants and the interdisciplinary character of the problem, which requires much effort on the part of the bioengineer.*
As part of this research, tests were carried out on anatomically correct (as regards geometry) polyurethane models of the human mandible. The plate implants actually used in the treatment of mandible angle fractures were employed in the osteosynthesis.
The local displacements of the bone fragments in the region of the union were analyzed in three directions, using the method of contactless optical measurement enabling the successive digital correlation of the image. Comparative analyses of the results obtained for each of the osteosyntheses performed in the same support and load conditions were carried out.

1. INTRODUCTION

In the facial skeleton the mandible is the bone which is often fractured. Men at the age of 20-40, constituting about 63% of the cases [7], are most prone to this injury. The main causes of such fractures are road accidents (43%) and assaults and batteries (34%). The other causes include the ones occurring during work (7%), falls during everyday activities (7%) and injuries suffered in sports (4%). The remaining percentage of fractures (5%) is classified as other various cases [6, 8, 9].
According to the literature, the shares of the particular parts of the mandible bone in the fractures are different, but it is commonly reported that the shaft and angle of the mandible are most often fractured, whereas the coronoid process and the ramus are least often fractured [7, 8, 9, 10]. The approximate frequency of fractures of the particular parts is shown in table 1.

Fractures of mandible areas (in per cent)								
acc. to authors	angle	shaft	symphysis	ramus	coronoid process	medial region	condyloid process	several areas
[5]	24.2	48.2	-	0.5	-	-	23.2	-
[6]	25.0	29.0	17.0	4.0	1.0	-	26.0	-
[7]	27.5	25.0	-	8.0	0.5	1.0	14.0	24.0
[8]	25.5	-	-	-	-	-	-	-

Tab.1 Fracture frequency depending on place of injury.

2. RANGE OF TESTS

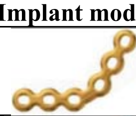
Comparative tests were carried using human mandible models anatomically correct as regards bone geometry. The displacements of bone fragments in the region of the mandible angle after an osteosynthesis were analyzed.

Fig.1 Mandible model osteotomized in left bone angle region.

Fig.2 Intraoperative photograph. Miniplates used to treat mandible angle fracture [16].

2.1 Mandible angle osteosynthesis

Various plate implants currently used in maxillofacial surgery were employed in the osteosynthesis. Five different systems for the osteosynthesis of mandible bone fragments, in the form of fixing titanium miniplates and proper clamping screws were used. Implants B, C, D are typically used for osteosynthesis purposes in the case of various fractures in the mandible bone region. Implants E, F are used in other cases of osteosynthesis, including orthognatic procedures, but they are also employed in the osteosynthesis after a mandible angle fracture. All the plate implants used in the osteosynthesis are shown in table 2.

No.	symbol	Implant model	Model name
1	B		(classic) six-mesh angle miniplate
2	C		four-mesh miniplate
3	D		six-mesh miniplate pre-bent by angle of 70º (fixed in oblique line)
4	E		two simple four-mesh plates
5	F		closed eight-mesh plate

Tab.2 Plate implants used in tests.

2.2 Test procedure

Geometrically correct models of the human mandible, osteotomized in the angle region, were used in the tests.
The support and load system was developed by the authors on the basis of the load model proposed by Armstrong [14].
In each of the osteosynthesis cases the tests were carried out in symmetric support and load conditions as well as in asymmetric support and load conditions. Moreover, each time prior to the osteotomy, which simulated the fracture of the mandible angle, a test was carried out on the correct mandible model. In two different cases, the selected support and load configuration simulated the basic functional activities of the masticatory organ.
The symmetric support and load [175N] configuration is responsible for the biting off of food whereas the asymmetric support and load [245 N] configuration is responsible for the mastication activity.

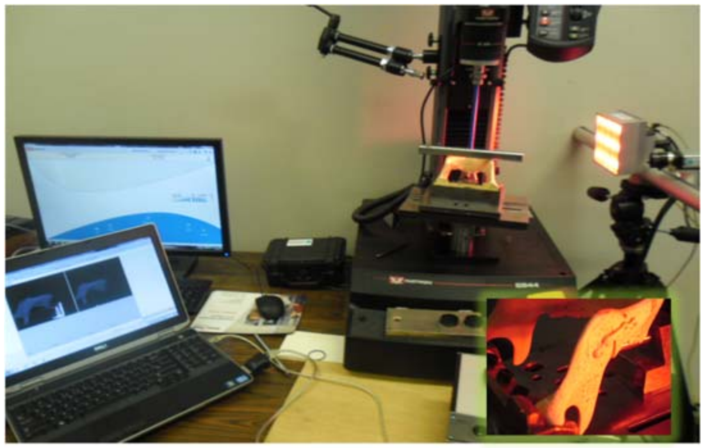


Fig.3 Measuring setup, close-up of exemplary mandible model osteosynthesized using four-mesh plate.

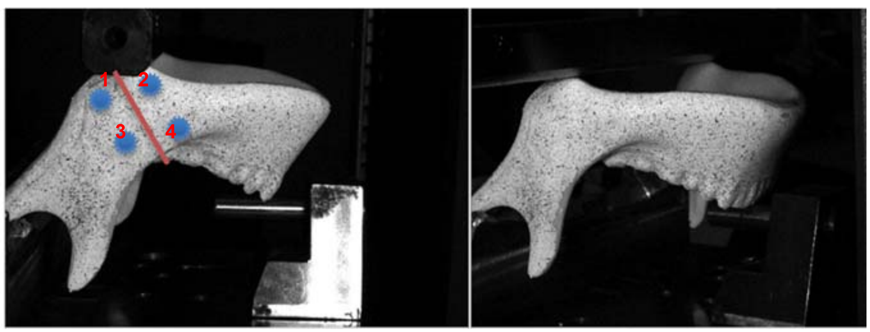
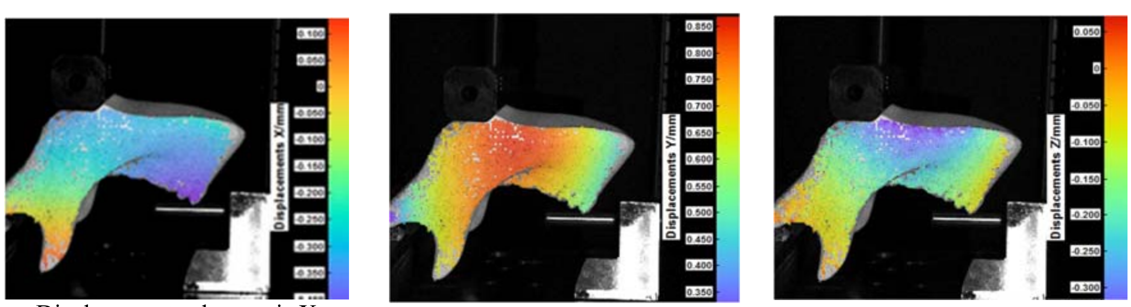


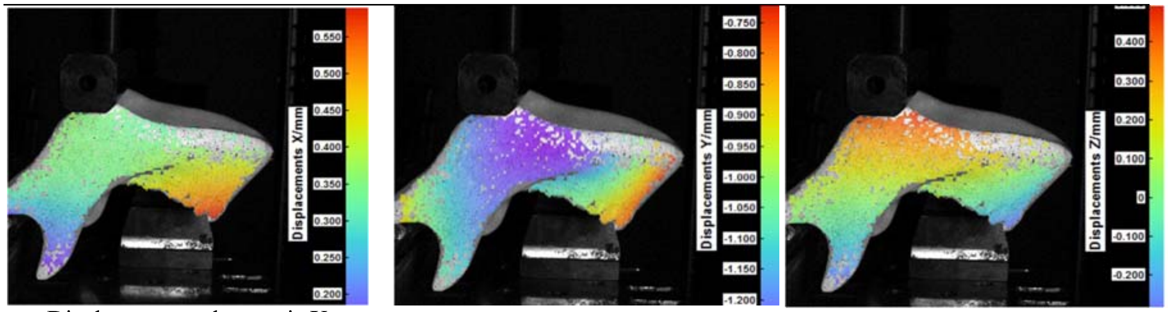
Fig.4 Image recorded by cameras during measurement performed for correct mandible model. Symmetric support and load configuration. Place of osteotomy and four selected analyzed areas of displacements are marked in photograph.

The contactless measurement of the displacements of bone fragments was employed after the mandible angle fracture and the osteosynthesis with plate implants. The contactless measurement was carried out using 3D digital image correlation system Q-400, DIC.



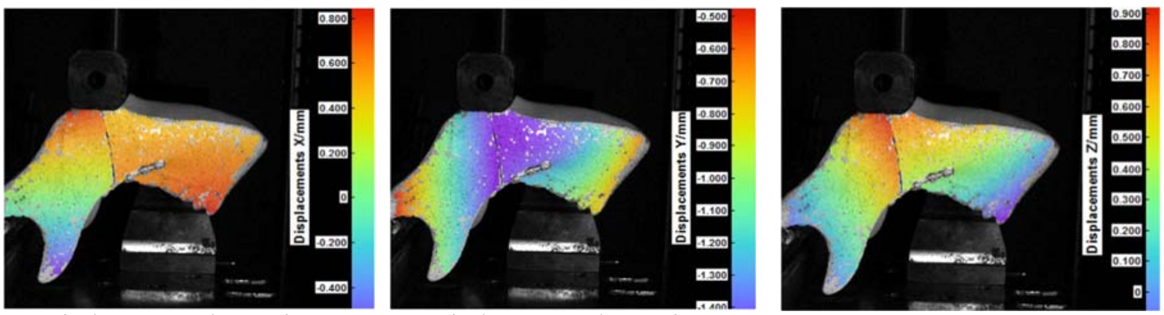
Displacements along axis X | Displacements along axis Y | Displacements along axis Z

Fig. 5 Distribution of displacements along axes X, Y, Z for functionally normal mandible under asymmetric load of 245 N.



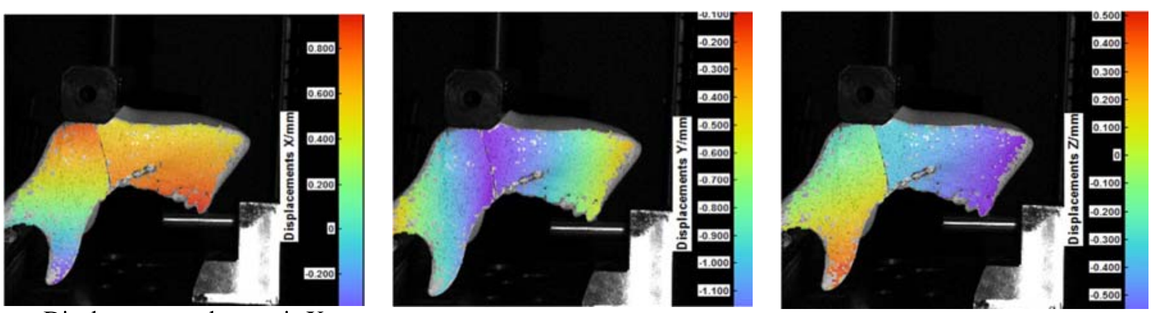
Displacements along axis X Displacements along axis Y Displacements along axis Z

Fig.6 Distribution of displacements along axes X, Y, Z for functionally normal mandible under load of 175 N in symmetric configuration.



Displacements along axis X Displacements along axis Y Displacements along axis Z

Fig.7 Distribution of displacements along axes X, Y, Z for mandible models with implant D – the oblique six-mesh miniplate under asymmetric load of 245 N.



Displacements along axis X Displacements along axis Y Displacements along axis Z

Fig.8 Distribution of displacements along axes X, Y, Z for mandible models with implant D – the oblique six-mesh miniplate under symmetric load of 175 N.

The averaged total displacements under the maximum load for each of the tested mandible models are presented below.

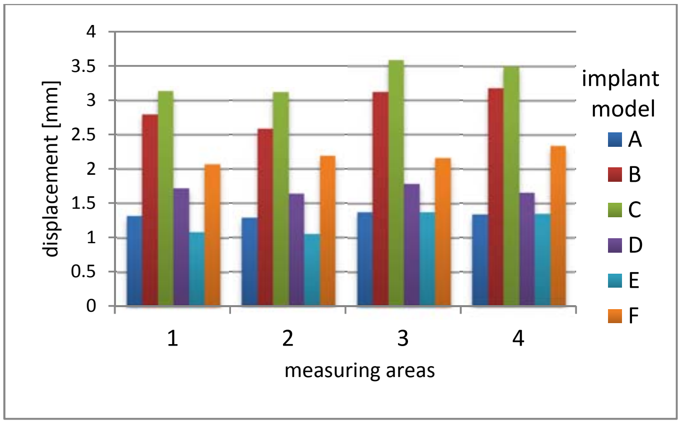


Fig.9 Total displacements of four measuring points for each model under maximum load in asymmetric configuration [model tab 1].

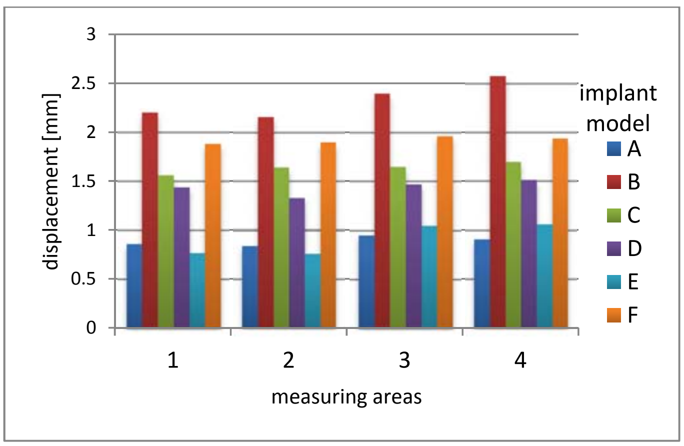


Fig.10 Total displacements of four measuring areas for each model under maximum load (175 N) in symmetric configuration [model tab 1].

All the averaged displacements of the mandible bone fragments under the maximum load are presented in the table below. The displacements in the three directions and the total displacements for each of the cases (the correct mandible model and the four different models after the osteosynthesis) are shown. The results in the table are presented according to the scheme: A – the correct model and the models of the mandible after the osteosynthesis: B – the six-mesh miniplate, C – the four-mesh miniplate, D – the oblique six-mesh miniplate, E – two four-mesh miniplates, F- closed eight-mesh plate.

displacement values under maximum load													
		symmetric configuration						asymmetric configuration					
area	displacement	**A**	**B**	**C**	**D**	**E**	**F**	**A**	**B**	**C**	**D**	**E**	**F**
1	total	**0.86**	2.2	1.56	1.44	0.77	1.88	**1.32**	2.8	3.14	1.72	1.09	2.07
	X	**0.32**	1.22	0.64	0.79	0.2	0.38	**0.36**	1.82	1.9	0.68	0.53	0.56
	Y	**-0.76**	-1.81	-1.34	-1.19	-0.72	-1.81	**-1.22**	-2.13	-2.85	-1.36	-0.91	-1.78
	Z	**0.25**	-0.29	0.47	-0.19	-0.19	0.31	**0.34**	-0.06	0.49	0.8	0.26	-0.9
2	total	**0.84**	2.16	1.64	1.33	0.76	1.90	**1.29**	2.59	3.12	1.64	1.05	2.19
	X	**0.25**	0.79	0.21	0.47	0.14	-0.14	**0.33**	0.81	0.73	0.23	0.29	-0.44
	Y	**-0.77**	-1.94	-1.47	-1.25	-0.75	-1.88	**-1.23**	-2.33	-3.03	-1.5	-0.98	-1.92
	Z	**0.18**	-0.54	0.71	0.03	0.09	-0.25	**0.16**	-0.78	0.2	0.63	0.23	-0.97
3	total	**0.95**	2.4	1.65	1.47	1.05	1.96	**1.38**	3.12	3.59	1.78	1.38	2.16
	X	**0.32**	0.98	0.63	0.55	0.23	-0.36	**0.34**	1.68	1.87	0.49	0.51	-0.16
	Y	**-0.84**	-2.12	-1.44	-1.32	-1.02	-1.91	**-1.28**	-2.62	-3.03	-1.54	-1.22	-1.87
	Z	**0.31**	-0.53	0.5	-0.34	-0.11	-0.28	**0.4**	-0.17	0.49	0.73	0.39	-1.06
4	total	**0.91**	2.58	1.7	1.51	1.06	1.94	**1.34**	3.18	3.5	1.66	1.35	2.34
	X	**0.29**	1.37	0.94	0.71	0.42	-0.50	**0.35**	1.86	1.81	0.59	0.56	-0.45
	Y	**-0.83**	-2.09	-1.35	-1.28	-0.97	-1.84	**-1.27**	-2.53	-3	-1.48	-1.21	-1.83
	Z	**0.24**	-0.65	0.44	-0.37	0.02	-0.34	**0.21**	-0.5	0.03	0.49	0.23	-1.38

Tab.3 Comparison of averaged displacement values under maximum load for each investigated case.

3. DISCUSSION

By analyzing the displacements of the mandible bone fragments one can accurately determine the quality of the osteosyntheses performed. According to the results presented in table 3 osteosynthesis E (two four-mesh plates) shows the closest fit to the correctly functional model results in 78% of the cases. No result most distant from the functionally correct model results was ever obtained. Osteosynthesis D (the six-mesh plate fixed in the oblique line) showed the second best fit to the reference results, but only in 6% of the cases, while showing the largest deviation from the reference value in 3% of the cases. The intermediate results for this osteosynthesis are quite often very close to the ones achieved by the variant with the two plates.

Then the experimental results obtained for the straight four-mesh plate were analyzed. For this osteosynthesis, results deviating from the reference were obtained in as many as 31% of the cases while results closest to the correct model were obtained in 16% of the cases. For the osteosynthesis performed using the six-mesh plate shaped into the letter L the displacement values deviated most from the reference ones: in as many as 66% of the cases deviations larger than the expected ones were registered. The stiffness of the whole system increased considerably. In quality terms, the last osteosynthesis which was analyzed can be compared to osteosynthesis E (two independent plates). Although this type of plate is dedicated to the osteosynthesis performed in the case of an osteotomy, it can also be successfully used in mandible angle fractures.

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