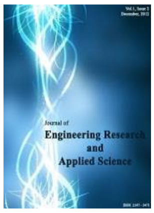
Journal of Engineering Research and Applied Science
Available at www.journaleras.com
Volume 9 (2), December 2020, pp 1486-1495
ISSN 2147-3471 © 2020



Biomechanical behaviour of different materials in partial fixed dental prsthesis :a finite element analysis

M. Pusur[1], A. Ozkan[2,a]

[1] Silverline Industrial R&D Center, Merzifon, Amasya, Turkey.
[2]Kocaeli University, Technology Faculty, Biomedical Engineering Department, Kocaeli, Turkey.

Accepted 10 September 2020

Abstract

In partial fixed dental prostheses/bridge crowns, to create an adequate aesthetic; composition specification must be realistic, reflects individuality and visual harmony. On the other hand, it must be biocompatible, non-toxic and must be fulfill mechanic specifications of the mandible and teeth. Many materials have been used for restorative purposes in dentistry until today. In this study, a three-dimensional mandible model was obtained from computed tomography (CT) images, and partial fixed dental prostheses/bridge crowns are created in the frontal region of mandible. For both (healthy mandible and prosthesis) models, the prosthesis geometries were designed with three different biocompatible materials (Titanium Alloy, Chrome Cobalt, Stainless Steel) and their mechanical analyzes were completed separately for each one, and compared with ANSYS® WORKBENCH software.

Keywords: mandible, material, ceramic, prosthesis, finite element method, characterization.

1. Introduction

Although aerodynamics is a part of gas dynamics and has Many materials have been used in fixed prostheses until today for restorative purposes. For this purpose, the use of acrylic resins, rubber and animal teeth did not give the desired results. As a result of the researches, it is focused on porcelain, where color harmony with natural teeth is also provided. The most important feature of porcelain is that it is tolerated by mouth tissues and does not absorb water. The word porcelain comes from the Greek word “Keramikos”. The exact equivalent is burnt substance. When we look at the history of humanity, it is seen that they have been used for centuries to serve various purposes [1]. Porcelain is now an indispensable material for increasing the quality of life every day in the modern world.

Today, porcelain is the only material that is functionally closest to the natural tooth, which can imitate the color of the natural tooth and is used for many purposes. It was supported by a metal substructure due to its fragility in the early days. In the following times, as the aesthetic demand increased, the research turned towards metal-free dental prostheses. In 1965, McLean and Hughes gained a new dimension with the proposal to strengthen the dental porcelain with alumina. After this stage, many studies were carried out to develop full ceramic systems. In order to strengthen the material; High resistance Ceramic infrastructures, ion exchange, controlled crystallization and the addition of resistant crystals into the glassy structure have been used. Nowadays, the aesthetic expectations of the patients are high and this necessitates the use of newly found and improved methods [2,3]. Metal-free dental prostheses have become prominent today because of the limited aestbridhetic conditions that need to be compromised [2-4]. In addition, since the metal part in the metal supported porcelain applications is gray, it is covered with a coating that will prevent the reflection of the metal. However, even if this coating is applied on the front teeth, the desired results cannot be achieved [6-10]. In metal-backed porcelain applications, in order for the coating to be fully successful, the main tooth needs to be cut and reduced too much. This causes the tooth to reach its nerves and the need for canal treatment. In some cases, hot-cold sensitivity is encountered [11-15]. In this study, a crown designed with a non-metallic ceramic material was evaluated biomechanically and its mechanical analyzes were performed.

2. Material and method

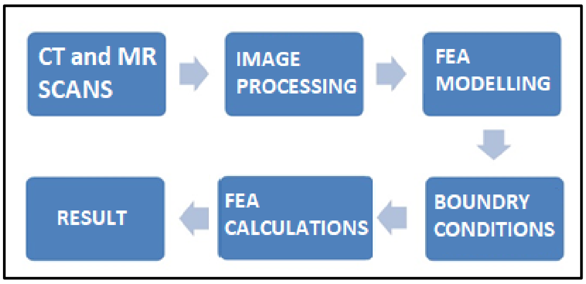
[a]Corresponding author: arif.ozkan@kocaeli.edu.tr

2.1. 3D modeling from CT and MR images

The models to be used in the study were obtained in Visualization and Medical Image Control System (MIMICS) software with visualization and segmentation processes after CT and MR images. In order to edit the models, it is necessary to use reverse engineering software as well as MIMICS software. GEOMAGIC. Software was used to edit undesirable geometries in the CT and MR images of the lesions and various non-bony structures formed in the models. The MIMICS software has different modules for editing CT and MR images [16-18].

Depending on the number of CT or MR layers, layer resolution, geometric and dimensional differences occur in the 3D bio-model geometries obtained. Therefore, arrangements are required with the help of reverse engineering software on 3D models obtained with the help of MIMICS. These adjustments are required in bone structures, the length of which does not exceed 5 mm (when CT sacan is not micro CT). Geometry arrangements of solid models converted to point cloud data have been realized with GEOMAGIC reverse engineering software. The edited 3D models are suitable for finite element analysis. Data transfer in steriolithography (STL) format takes place between GEOMAGIC and MIMICS in either ASCII or binary format [19-21]. Flow chart can be seen at Figure 2.1.

Figure 2.1. Flow chart of bio-model generating**.**



CT and MR image layers can be used in the MIMICS software as long as the DICOM (The Digital Imaging and Communications in Medicine) format. The CT and MR sections are given in Figure 2.5. With this solid surface modeling tool, which is integrated into the MIMICS content, a 3D solid model of the CT or MR image is obtained [22,23].

2.2. Creating mandible and partial fixed dental prosthesis/bridge crowns models

Computed Tomography (CT) images of a healthy person of average face style and shape were used for modelling mandible model, used in this study. CT images were obtained with the Toshiba Aquilion CT scanner device. Since it is appropriate to make a CT scan as often as possible for modeling that can be a one-to-one reference, a CT scan with a resolution of 512 x 512 pixels with 500 parallel layers with a cross section range of 0.2 mm has been performed. The images were recorded from the CT device in DICOM (Digital Imaging and Communications in Medicine) format. DICOM layers are used to generate bio-model of the whole mandible. These images have been processed with the MIMICS® (Materialise's Interactive Medical Image Control System) [39] software for exacted mandible geometry [24-28].

The bio-model geometry was recorded as a point cloud. The arrangement of the measurement and surface lines suitable for the real model was transferred to GEOMAGIC® (Raindrop Inc.), a reverse engineering program, via this point cloud data to eliminate the surface errors [29,30]. All the surface errors on the mandible bio-model (surface coating to the point cloud, surface roughness removal, detection and closure of open holes, wiping of excess surfaces, etc.) eliminate with the strong one to one surface design tool with GEOMAGIC®. Bio-model of mandible were transferred to Solid Edge19® (Siemens 3D Design System Corp.) software for front teeth modelling [31-34]. 3D modeling procedure chart and models can be seen on Figure 2.2.

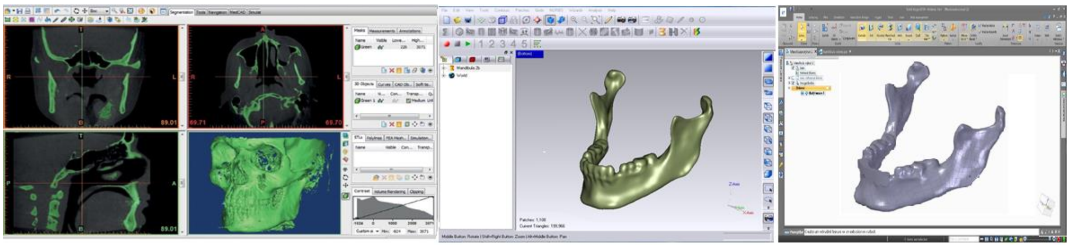


Figure 2.2: 3D Bio-modeling procedures and mandible model.

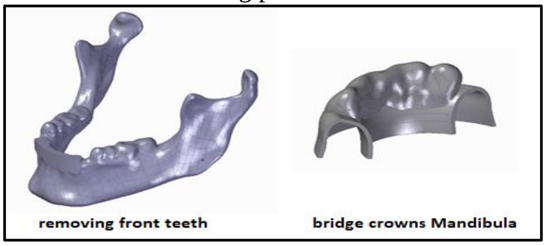


Figure **Hata! Belgede belirtilen stilde metne rastlanmadı.**.3. Teeth removed mandibular and partial fixed dental prosthesis/bridge crown mandibular models.

Front teeth were deleted and designed suitable partial fixed dental prosthesis/bridge crown application in Solid Edge software. Figure 2.3 shaped chin and ceramic bridge crown models.After the model design finalizing phase the partial fixed dental prosthesis/bridge crowns were designed in accordance with the section where the teeth were taken. Three different material details were designed and defined.

2.3 Mesh and material properties

In the finite element analysis (FEA), the mathematical model definition to be defined with the help of mesh assignment (mesh). This assignment is obtained by dividing the model by the number of corners and edges as a mathematical expression. For this study, the volumetric mesh was defined with 10 node quadratic tetrahedron (solid187) elements. As far as the characteristics of the computer where finite element analyses are performed, all models have been analyzed with an average of 517,000 nodes and 356,000 elements (geometry evaluations of the models). A mesh was laid on the crown in the same way as the mandible [35-38]. The meshed of the partial fixed dental prosthesis/bridge crown and mandible is given in Figure 2.4.

Table **Hata! Belgede belirtilen stilde metne rastlanmadı.**.1. Material properties

	Poisson rate (ν)	**Modulus of Elasticity (E) GPa**	**Yield Strength (MPa)**
Ti-6Al-4V	0.342	113.8	782
Stainless Steel	0,30	195	170
Aluminum	0.25	375	2600
Zirconium	0.31	200	4100
Cortical Bone	0.3	14	

2.4 Loading and boundary conditions

Stress values on the mandible increase with the opening and closing of the chewing, eating and drinking activities. The partial fixed dental prosthesis/bridge crowns must be able to respond to situations where stress reaches a maximum. The biting force cause higher effect on the anterior teeth so partial fixed dental prosthesis/bridge crown effected as well. Our experiments have been carried out on the basis of loading biting force. It is applied on the front teeth as a single load that based on the chewing force of 150 Newton (N) in the vertical direction (-z) due to the mechanical loading direction of mandible [39,40]. The loading and boundary conditions of mandible model can be seen on Figure 2.5. The boundary conditions are determined to be in the medial condyle region (A) as seen in Figure 2.5.

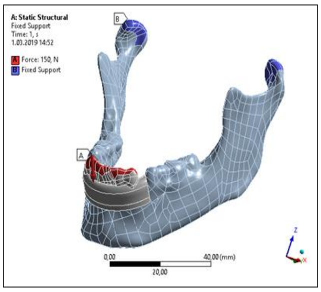


Figure **Hata! Belgede belirtilen stilde metne rastlanmadı.**.5. Loading and boundary conditions.

3. Results and discussion

In this study, the models are an approximation to clinical conditions, and to this end, modeling the exact geometry of the mandible was designed, including the prosthesis quality. However, a whole true designed model with computer aided designed was assumed and this does not simulate exact clinical conditions. In the three-dimensional finite element analyses, the results depend on many important factors, including the biological structure, border conditions, and definition of the material properties and its' techniques [41,42]. In this study, different suitable material determinations for natural appearance were made in place of the weakened front teeth in the mandible fracture. Partial fixed dental prosthesis/bridge crowns were compared with the metallic and ceramic materials using with the finite element method. The re-designed partial fixed dental prosthesis/bridge crowns have different material properties, the amount of deformation and the stress amounts for the combination of different biomaterials of each geometry have been examined separately.

3.1 Zirconia alloy partial fixed dental prosthesis/bridge crown

In the partial fixed dental prosthesis/bridge crown model with zirconia, maxium Von-misses stress value was obtained 390.21 MPa. In the frontal region of the mandible, maximum value of 33.7 MPa was occurred. When the zirconia partial fixed dental prosthesis/bridge crowns were placed, there was no change in the maximum Von-misses stress in the entire model. FEA results can be seen at Figure 3.1.

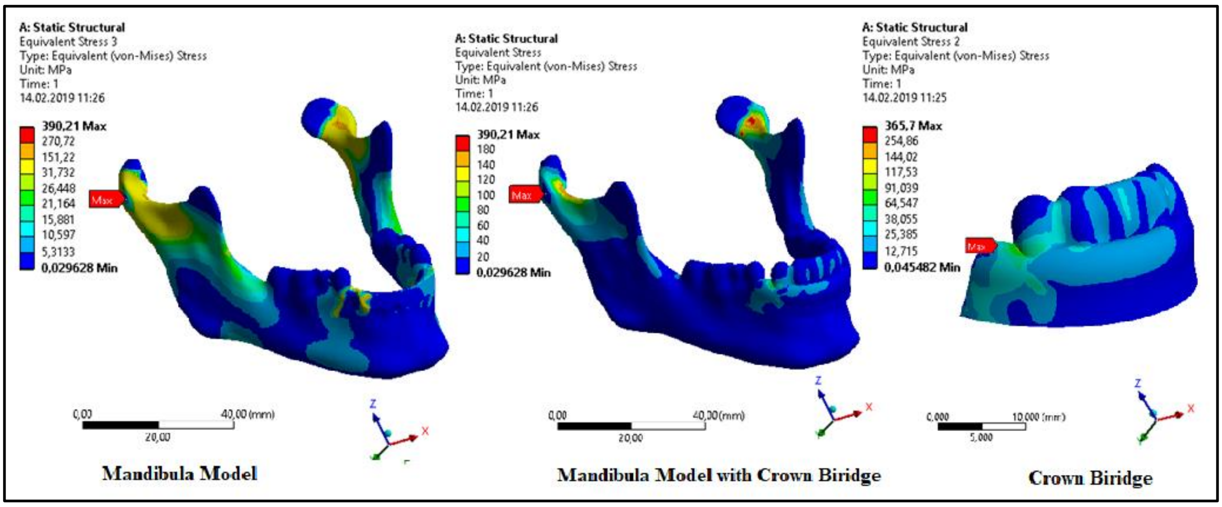


Figure 3.1. Zirconia Alloy FEA results.

The maximum Von-misses stress was measured as 365.7 MPa when force was applied alone on the zirconia alloy bridge crown. The tension on the product is based on the force applied, since the yield strength value of Zirconia is less than 900 MPa.

3.2 Alumina partial fixed dental prosthesis/bridge crown

In the model with alumina partial fixed dental prosthesis/bridge crowns, the maximum Von-misses stress value 561.74 MPa on the whole application was obtained. The maximum stress was occurred on near the fixed areas the value of 99.7 MPa. The model is based on the applied force since the alumina is within the boundary limit of 2600 MPa. Maximum von misse stress on the mandible in the alumina bridge crown application was measured as 391.5 MPa. The maximum von misses stress in the alumina alloy bridge crown model was 561.74 MPa. This value is less than the Alumina yield limit value of 2600 MPa. For this reason, it has been determined that the selected material is based on the applied force.

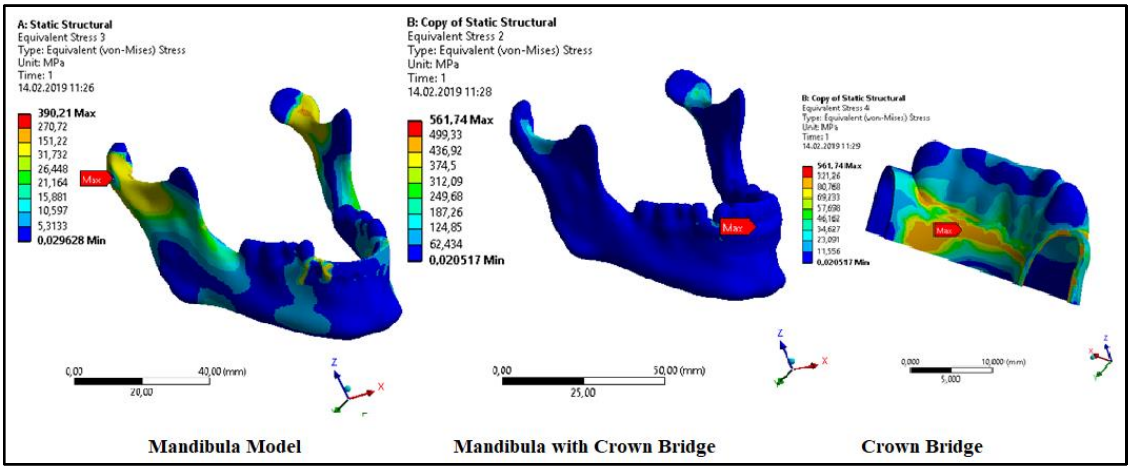


Figure 3.2. Alumına Alloy FEA results.

3.3 Titanium alloy partial fixed dental prosthesis/bridge crown

Titanium alloy (Ti-6Al-4V) crown model belongs to the group defined as metal supported model. Natural tooth color coatings are made on titanium alloy. As a result of the porcelain coating, an appearance close to the natural tooth color is obtained. In this study, it was exposed to the same loads with the same metal-free crown under the same conditions. The results are examined in detail below. In the titanium alloy bridge crown model, the maximum Von misses stress value on crown application was achieved as 127.65 MPa. The maximum strain on the bone near the fixed areas was 113.47 MPa. The model is based on the applied force since the titanium mechanical properties limit is within the maximum value of 782 MPa.

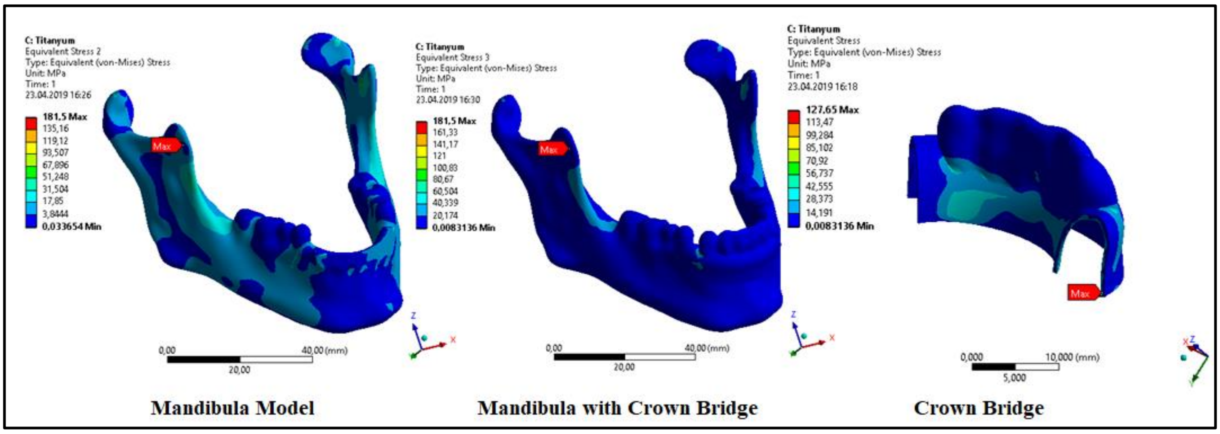


Figure 3.3. Titanium Alloy FEA results.

3.4 Stainless steel partial fixed dental prosthesis/bridge crown

Stainless steel partial fixed dental prosthesis/bridge crown model falls into the group defined as metal supported model. In this study, it was selected for comparison and analyzed according to the applied force. As a result of the porcelain coating, an appearance close to natural tooth color is obtained. In this study, it was exposed to the same loads with the same metal-free crown under the same conditions. The results are examined in detail below. The total stress on the whole model was found to be max.180.52 MPa. Min. The amount of stress was determined to be 3.06 MPa. Max. The place where it was measured was measured as the lower part of the anterior palate. The max. stress value was determined to be 157.47 MPa.

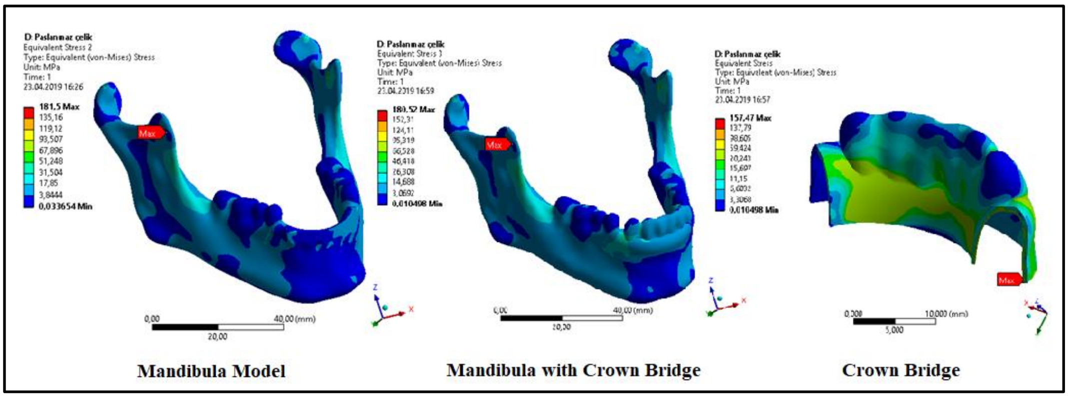


Figure 3.4. Stainless Steel Alloy FEA results.

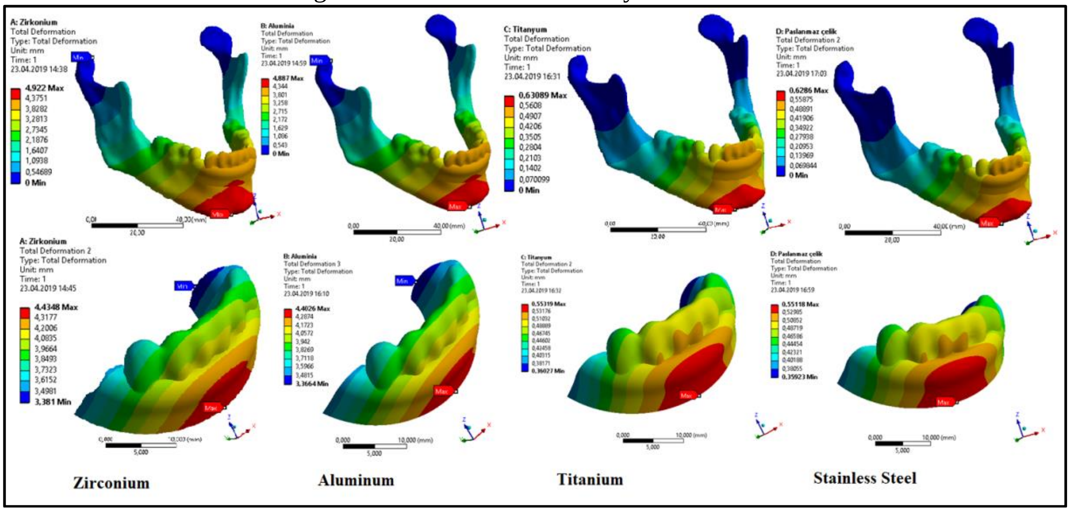


Figure 3.5. Total Deformation Results

Total deformation values for the 4 materials examined are given in Figure 3.5. Comparison of total deformation and stress values of the 4 different materials examined are given in tables 3.1 and 3.2.

Table 3.1. Total Stresses

Total Stresses					
		Stainless Steel (MPa)	Titanium Alloy (MPa)	Alumina (MPa)	Zirconia (MPa)
Mandible	Max.	180.52	181.5	391.5	391.21
	Min.	0.048488	0.033654	0.03381	0.029628
Bridge Crowns	Max	157.47	127.65	561.74	365.7
	Min.	0.010498	0.0083136	0,020517	0,045482
Man. Bridge Crowns	Max	180.52	181.5	561.74	390.21
	Min	0.010498	0.0083136	0.020517	0.029628

Table 3.2. Total Deformation

Total Deformation					
		Stainless Steel (MPa)	Titanium Alloy (MPa)	Alumina (MPa)	Zirconia (MPa)
Bridge Crowns	Max.	0.55118	0.55319	4.4026	4.4348
	Min.	0.35923	0.36027	3.3664	3.381
Man. Bridge Crowns	Max.	0.6286	0.63089	4.887	4.922
	Min.	0.069844	0.070099	0.543	0.54689

4. Conclusion

Crowns with metal support give better results than all non-metallic materials. In addition, considering the aesthetic and natural appearance, zirconia partial fixed dental prosthesis /bridge crown gives better results than alumina (Figure 4.1). In Figure 4.2, on the whole model, the responses under the force created in the same direction with the same value are compared. It is understood that the zirconia alloy model gives better results.

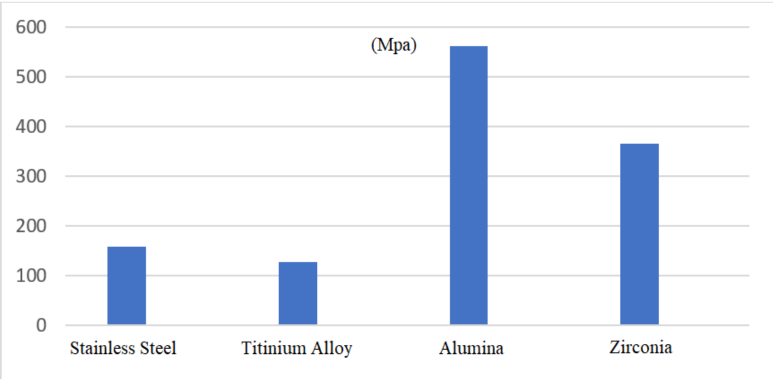


Figure 4.1. Stress details between materials used

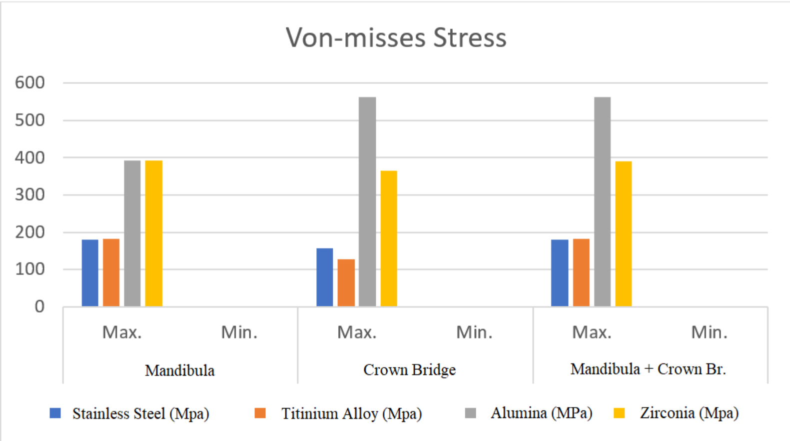


Figure 4.2. Responses of the materials used on the mandible

When comparisons are made for the total displacements, it has been observed that the Zirconia model gives better results. Displacement comparison of other models can be seen in Figure 4.3. The tension and total displacement amounts of partial fixed dental prosthesis/bridge crowns applications with the same material and the same geometry vary naturally under the same force. This is also expected mechanically. According to these results; It should be taken into consideration that the location of the geometry, the material and the partial fixed dental prosthesis/bridge as well as the strength to be applied are very important and the literature studies referring to this situation also explain similar expressions in general [41-49]. The von-misses stress on the partial fixed dental prosthesis/bridge crowns were generally found on the surfaces in contact with the mandible. The results obtained in this study form a unity of expression in this direction.

The tension and total displacement amounts of partial fixed dental prosthesis/bridge crowns applications with the same material and the same geometry vary naturally under the same force. This is also expected mechanically. According to these results; It should be taken into consideration that the location of the geometry, the material and the partial fixed dental prosthesis/bridge as well as the strength to be applied are very important and the literature studies referring to this situation also explain similar expressions in general [41-49]. The von-misses stress on the partial fixed dental prosthesis/bridge crowns were generally found on the surfaces in contact with the mandible. The results obtained in this study form a unity of

expression in this direction.

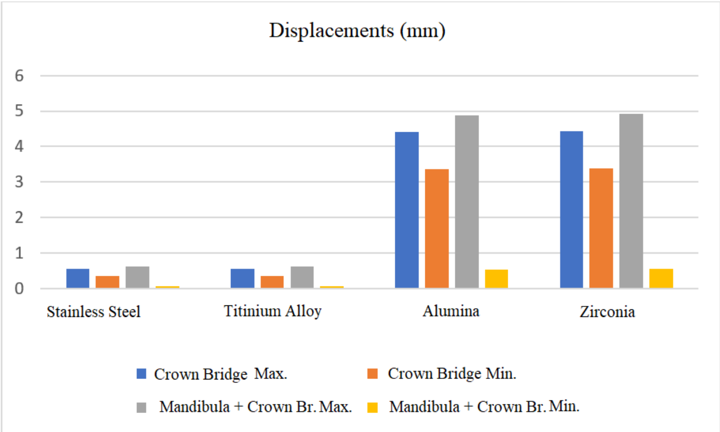


Figure 4.3. Comparisons of total deformation values

In the light of these explanations, the following conclusions have been obtained within the limitations of this study;

- As a result of the bite force applied in the application of zirconia alloy partial fixed dental prosthesis/bridge crowns, it was observed that the stress accumulation was on the mandible rather than the partial fixed dental prosthesis/bridge crown.
- It has been revealed that there is not a very high strength difference between Alumina alloy partial fixed dental prosthesis/bridge crown application and Zirconia bridge crown, but zirconia based ceramic partial fixed dental prosthesis/bridge crown applications give better results.

According to metal supported applications, applications without metal support; It has been understood that it only gives adequate results and new applications must be made with the material technology that is developing in the lower backing material. Also that is biocompatible derivatives of the generation composite

References

[1] Malkondu Ö, Tinastepe N, Akan E, Kazazoğlu E. An overview of monolithic zirconia in dentistry. Biotechnology & Biotechnological Equipment, 30(4):644-52, 2016.

[2] Yoon HI, Yeo IS, Yi YJ, Kim SH, Lee JB, Han JS. Effect of surface treatment and liner material on the adhesion between veneering ceramic and zirconia. Journal of the mechanical behavior of biomedical materials 40:369-74, 2014.

[3] Özden Y, E, Monolithic Zirconia Effect of Change in Sintering Time on Marginal and Internal Range in Restorations, PhD Thesis, Hacettepe University, 2017.

[4] Carames J, Tovar Suinaga L, Yu YC, Perez A, Kang M. Clinical Advantages and Limitations of Monolithic Zirconia Restorations Full Arch Implant Supported Reconstruction: Case Series. International journal of dentistry, 2015:392-496, 2015.

[5] Alpert B, Engelstad M, Kushner GM. Invited review: small versus large plate fixation of mandibular fractures. J Craniomaxillofac Trauma. 1999;5: 33-9.

[6] Şirin Y, Said M, Limani E, Soley S, : Sagittal Split Effects of Osteotomy Technique on In-Vitro Biomechanical Strength of Titanium Plates, İstanbul University Journal of the Faculty of Dentistry, 45(3), 2011.

[7] Takahashi, H, Moriyama, S., Furuta, H., Matsunaga, H, Sakamoto, Y., Kikuta, T, "Split Ramus Osteotomy Fixed with Resorbable Compared with Titanium Bicortical Screws in Mandibles of Sheep," Head & Face Medicine, 6:4, 2010.

[8] Chuong, C, Borotikar, B, Schwartz-Dabney, C, Douglas Sinn, P., "Mechanical Characteristics of the Mandible After Bilateral Sagittal Split Ramus Osteotomy: Comparing 2 Different Fixation Techniques," American Association of Oral and Maxillofacial Surgeons J Oral Maxillofac Surg, 63:68-76, 2005.

[9] Grahramanzadeh ASL, H., Kovacı, H., Kaymaz, İ, Alsaran, A, Çelik, İ, "Simulation of placement of mini plates used on jaw fractures on sheep jaw and stress analysis with FEM"

TİSKON 2011, Samsun, 31-39, 2011.
[10] Karatasli O, Kursoglu P, Capa N, Kazazoglu E. Comparison of the marginal fit of different coping materials and designs produced by computer aided manufacturing systems. J. Dental Materials, 30(1):97-102, 2011.
[11] Esen A., Comparison of Stability of Titanium and Resorbable Plate and Screw Fixations in Mandible Angulus Fractures, Doctoral Thesis, Selçuk Universities, 2008.
[12] Ayalı A., Investigation of Biomechanical Effects of Different Fixation Methods Applied in Favorable and Unfavorable Fractures of Mandibular Angulus Region by Finite Element Analysis Method, Ph.D. Thesis, Near East University, 2012.
[13] Denry I, Kelly JR. State of the art of zirconia for dental applications. Dental materials: official publication of the Academy of Dental Materials, ;24(3):299-307, 2008.
[14] Ömezli M., Dayı E., Ayrancı F., Kaya G., Mandibular Condyle Fractures And Treatment Methods, Cumhuriyet Univ. Dent Journal., 15(1):63-70, 2011.
[15] Ministry of Health Ankara Provincial Health Directorate Emergency Health Services Branch, Basic First Aid Practices Training Book, Ankara, 2006.
[16] İrkören S., Sivrioğlu N., Bulut B., Sonel A., Ceylan E. Retrospective Analysis of 63 Mandibular Fracture Cases Operated Within Three Years. Adnan Menderes University Faculty of Medicine Journal,12(3) 2011.
[17] Akdemir K., Lower Jaw Fractures and Treatment Methods in Children, Graduation Thesis, Ege University, Faculty of Dentistry, 2007.
[18] Gutwald R, Alpert B, Schmelzeisen R. Principle and stability of locking plates. Keio J Med., 52(1):21-24, 2003.
[19] Alpert B, Gutwald R, Schmelzeisen R. New innovations in craniomaxillofacial fixation: the 2.0 lock system. Keio J Med 52(2):120-127, 2003.
[20] Chiodo TA, Ziccardi VB, Janal M, Sabitini C. Failure strength of 2.0 locking versus 2.0 conventional Synthes mandibular plates: A laboratory model. J Oral Maxillofac Surg 64(10):1475-1479, 2006.
[21] Tao J, Han D. The effect of finish line curvature on marginal fit of all-ceramic CAD/CAM crowns and metal-ceramic crowns. Quintessence international (Berlin, Germany:1985).;40(9):745-52, 2009.
[22]
[23] Pimenta MA, Frasca LC, Lopes R, Rivaldo E. Evaluation of marginal and internal fit of ceramic and metallic crown copings using x-ray microtomography (micro-CT) technology. The Journal of prosthetic dentistry,114(2):223-8, 2015.
[24] Boitelle P, Mawussi B, Tapie L, Fromentin O. A systematic review of CAD/CAM fit restoration evaluations. Journal of oral rehabilitation, 41(11):853-74, 2014.
[25] Ueda K, Beuer F, Stimmelmayr M, Erdelt K, Keul C, Guth JF. Fit of 4-unit FDPs from CoCr and zirconia after conventional and digital impressions. Clinical oral investigations, 20(2):283-9, 2016.
[26] Belli R, Frankenberger R, Appelt A, Schmitt J, Baratieri LN, Greil P, et al. Thermalinduced residual stresses affect the lifetime of zirconia-veneer crowns. Dental materials: official publication of the Academy of Dental Materials,29(2):181- 90, 2013.
[27] Zhang H, Kim BN, Morita K, Keijiro Hiraga HY, Sakka Y. Effect of sintering temperature on optical properties and microstructure of translucent zirconia prepared by highpressure spark plasma sintering. Science and technology of advanced materials, 12(5):055003, 2011.
[28] Almazdi AA, Khajah HM, Monaco EA, Jr., Kim H. Applying microwave technology to sintering dental zirconia. The Journal of prosthetic dentistry, 108(5):304-9, 2012.
[29] Lee KH, Yeo IS, Wu BM, Yang JH, Han JS, Kim SH, et al. Effects of Computer-Aided Manufacturing Technology on Precision of Clinical Metal-Free Restorations. BioMed research international, 619-627 , 2015.
[30] Hamza TA, Ezzat HA, El-Hossary MM, Katamish HA, Shokry TE, Rosenstiel SF. Accuracy of ceramic restorations made with two CAD/CAM systems. The Journal of prosthetic dentistry,109(2):83-7, 2013.
[31] Atik F., Comparison of Material and Geometry Differences of Plate-Fixators Used in Mandibular Fractures According to Fracture Types, Master Thesis, Düzce University, 2013.
[32] As N. T., Retrospective Analysis of Facial Fracture Etiology, PhD Thesis, Haydarpaşa Numune Training and Research Hospital, 2008.
[33] Açıkel C., Saray A., Yılmaz K., A Case of Maxillofacial Trauma Requiring Re-Surgery, Acıbadem University Journal of Health Sciences, 2(2), 2011.
[34] Şirin Y., Said M., Limani E., Soley S., The Influences Of Two Sagıttal Splıt Osteotomy Technıques On The In Vıtro Bıomechanıcal

Stabılıty Of Tıtanıum Plates, İstanbul Üniversitesi Diş Hekimliği Fakültesi Dergisi, ,45(3), 2011.
[35] Alnıaçık G., Investigation of Stress Generated by Mandibular Overdenture Prostheses on Implants Applied at Different Levels, Ph.D. Thesis, Selcuk University, Institute of Health Sciences, 2011.
[36] Deniz K., Investigation of the Effect of Different Fracture Types on the Stability of Titanium Plate and Screw Fixation in Mandible Angulus Fractures by Finite Element Analysis, Ph.D. Thesis, Başkent University Institute of Health Sciences, 2011.
[37] Müftüoğlu G., Evaluation of Locked and Unlocked Plate and Screw Systems in Mandibular Lateral Defects by Three-Dimensional Modeling and Finite Element Analysis, Ph.D. Thesis, Başkent University, 2013.
[38] Çilingir A., Experimental and Numerical Analysis of Stresses in the Lower Jaw in Lower and Full Implant Supported Dentures, Ph.D. Thesis, Istanbul University, Institute of Health Sciences, 2005.
[39] Karatasli O, Kursoglu P, Capa N, Kazazoglu E. Comparison of the marginal fit of different coping materials and designs produced by computer aided manufacturing systems. Dental Materials Journal.;30(1):97-102, 2011.
[40] KayabasI O, YüzbasIoglu E, ErzincanlI F. Static, dynamic and fatigue behaviors of dental implant using finite element method. Adv Eng Softw, 37(10): 649-658, 2006.
[41] Özkan, A., "Computer Aided Three Dimensional Modeling and Kinematic Analysis of Human Knee Mechanism ", Ph.D. Thesis, Kocaeli University Institute of Science Mechanical Education, Kocaeli, 2010.
[42] Oğuz Y., Investigation of the Use of Locked Screw and Plate System in Sagittal Split Ramus Osteotomy with Three-Dimensional Modeling and Finite Element Analysis, Ph.D. Thesis, Başkent University, Faculty of Dentistry, 2007.
[43] Arat Z., Investigation of the Effect of Implant Number and Holder Type on Bone Stress
[44] Distributions in Mandibular Implant Supported Removable Dentures by Finite Element Analysis, Ph.D. Thesis, Istanbul University, Institute of Health Sciences, 2010.
[45] Sancaklı E., Evaluation of Stress Distribution of Bar Supported Implant Prosthesis in Lower Toothless Jaw Using Finite Elements Stress Analysis Method, Ph.D. Thesis, Istanbul University, Institute of Health Sciences, 2006
[46] Ünal D., "Medical Imaging Techniques ", Master Thesis, Gazi University Gazi Education Faculty, Department of Education Science and Mathematics Education, Ankara, 2008.
[47] Çelik T., Stress Distribution of Dynamic Hip Nail in the Femoral Fractures Between the Trochanter According to the Location of the Hip, Master Thesis, Kocaeli University, Institute of Science, 2012.
[48] Türker, M. ve Yücetaş, Ş., Oral, Dental and Maxillofacial Diseases and Surgery, (3rd. Ed.), Özyurt Matbaacılık, 2004.
[49] Atik F., Özkan A., Uygur İ., Comparison of Stress and Displacement Behavior of Human Thigh Bone and Hip Replacement, Sakarya University Journal of Institute of Science, 16(3), 249-253, 2012.