Süleyman Demirel Üniversitesi
Mühendislik Bilimleri ve Tasarım Dergisi
2(3),ÖS:BiyoMekanik2014, 253-259, 2014
ISSN: 1308-6693

Suleyman Demirel University
Journal of Engineering Sciences and Design
2(3),SI:BioMechanics2014, 253-259, 2014
ISSN: 1308-6693

EFFECTS OF DENTAL AND ZYGOMATIC IMPLANTS ON STRESS DISTRIBUTION IN ZYGOMATIC BONE

Canan AKAY*[1], Suat YALUĞ[2], Mehmet DALKIZ[3]
[1]Prosthesis Specialist, Ankara, Turkey
[2] Gazi University, Prosthetic Dentistry, Ankara, Turkey
[3] Mustafa Kemal University, Prosthetic Dentistry, Hatay, Turkey

Keywords
Zygomatic implant
Obturator
Three- dimensional finite-element analysis
Stress distribution

Abstract
Prosthetic rehabilitation of the upper jaw in patients with expansive bone and soft tissue defects is still a significant problem lack of retantion and stability. Zygomatic implant is an alternative method for these patients. The purpose of this research was to evaluate the stress distribution in the zygomatic bone for three different implant-retained obturator prostheses configuration in a premaxillary with unilateral maxillary defect using a three dimensional finite element stress analysis. 3- dimensional finite element models were constructed based on computed tomograph data. Model 1; one zygomatic implant on defected side, two dental implant on nondefected side, model 2; two dental implant on nondefected side, model 3; one zygomatic implant on each side of the maxilla additionally one dental implant on non defected side. Bar attachments were used as superstructure. Vertical load 150 N was applied in three different ways and the stress distribution were observed and compared. In all loading conditions model 3 when compared another models, shows highest maximum principle stress value on zygomatic bone. Use of zygomatic implant with dental implant in the same part of the maxilla increased the stress values of the zygomatic bone.

DENTAL VE ZİGOMATİK İMPLANTLARIN ZİGOMATİK KEMİKTEKİ STRES DAĞILIMINA ETKİSİ

Anahtar Kelimeler
Zigomatik implant
Obturator
3 boyutlu sonlu elemanlar analizi
Stress dağılımı

Özet
Üst çenede geniş kemik ve doku defektlerine sahip olan hastalarda retansiyon ve stabilite eksikliği protetik rehabilitasyon için ciddi bir problemdir. Bu hastalarda zigomatik implantlar alternatif bir tedavi metodudur. Bu çalışmanın amacı premaksilla ile tek taraflı maksiller defektlerde, 3 farklı şekilde dizayn edilmiş implant destekli obturator protezin zigomatik kemikte yarattığı stresi üç boyutlu sonlu elemanlar stress analiz yöntemiyle değerlendirmektir. Üç boyutlu sonlu eleman modelleri bilgisayarlı tomgrafi verilerine dayandırılarak hazırlandı. 1. model de bir adet zigomatik implant defekt tarafına, iki adet dental implant defekt olmayan tarafa, 2. model de iki adet dental implant defekt olmayan tarafa, 3. model de; defekt olan ve olmayan tarafa birer adet zigomatik implant ilave olarak defekt olmayan tarafa bir adet dental implant yerleştirilmiştir. Üst yapı olarak bar ataçmanlar kullanılmıştır. Dikey yönde 150 N kadar dikey kuvvet üç farklı yolla uygularak gözlenmiş ve karşılaştırma yapılmıştır. Bütün yükleme koşullarında 3.model diğer modeller ile karşılaştırıldığında zigomatik kemikte en yüksek maximum principle stress değerini göstermiştir. Zigomatik implantın dental implant ile maksillanın aynı bölgesinde kullanılması zigomatik kemikte maksimum principle stres değerlerini artırmıştır.

* Corresponding author: cnngcr2@hotmail.com

1. Introduction

Maxillary defects are generated by surgical treatment of benign or malignant neoplasms, congenital malformation, and by trauma. The size and location of the defects impact the degree of impairment. Such patients present complexity in speech, control of secretions, mastication, phonetics, deglutition, swallowing, and poor esthetics.This effect diminishes the patient's quality of life and self esteem. To accomplish such problems obturator prostheses are provided. Prosthodontic treatment will restore the patients to a normal or near normal level of function (Patton et.al., 1994; Sharma et al., 2005; Ahmet et al., 2007; Keyf, 2001; Ahila et al 2011).

Construction of a maxillectomy obturator for any maxillary defect needs suitable retention, stability. Osteointegrated implants may act as a preferable source of retention provided appropriate quality and quantity of bone is available. Unfortunately, these anchorage parts are frequently limited because of tissue loss or resection, may be compromised by radiation of tissue beds and may be localized in patterns that prohibit effective anterior posterior spread and cross-arch stabilization.(Parel et al.,2001)
The zygoma implant is a product of the remote bone anchorage concept and originally was developed for use in patients with challenging maxillary defects. More than 20 years of follow-up at the Brånemark Osseointegration Center (Göteborg, Sweden) has demonstrated a remarkably high rate of success for this implant when it is used to support a variety of maxillary defect prostheses.

The zygomatic bone was used for anchorage and support of a long fixture that together with conventional fixtures could be used as anchorage for epistheses, prostheses and obturators (Weischer et al 1997; Aparicio et al 2010).

According to the presents authors' experiences, high primary stability can also be achieved with zygomatic implants but they mentioned that for successful treatment the important point is first of all careful patient selection, appropriate surgical approach and favorable prosthetic designs for biomechanic loadings (Aparicio et al 2006).

Al-Nawas et al emphasized that 9 of 20 zygomatic implants showed bleeding and increased probing depths that may be because of couldn't supplied oral hygiene caused by the positioning of the zygomatic implant head, abutment and the design of the prosthesis (Al-Nawas et al, 2004).

The aim of this study was to investigate, by using finite element stress analysis, the effect zygomatic implant application of the stress distribution on the zygomatic bone when Aramany Class IV obturator prosthesis was subjected to three different loadings.

2. Materials and Methods

2.1. Construction of craniofacial bone models

The construction of finite element models considered in this research are generated of mucosa, compact bone, trabecular bone, zygomatic implant (Branemark System, Nobel Biocare AB, Goteborg, Sweden), dental implant, bar attachment system (Institute Straumann, Waldenberg, Switzerland), and obturator prosthesis (Figure 1). Cortical bone with 1.5-mm thickness was uniformly defined around the trabecular core body. Mucosa was sustained to be 1.5-mm thickness. Standard dental implants with a diameter of 4.1 mm and a length of 10 mm, zygomatic implants with a diameter of 4 mm and length of 35 mm, titanium U shaped dolder bar with a height of 3 mm, and titanium dolder bar matrix with a height of 4.5 mm were modeled in all models generated. The zygomatic and dental implants were oriented to the defective maxilla in three different configurations.

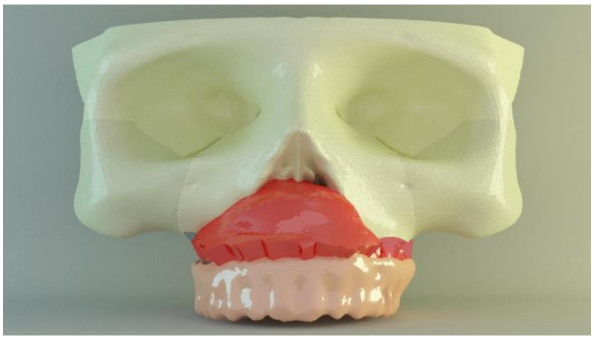


Figure 1. Configuration of finite element model

2.2. Boundary conditions

The defective side of the maxilla and zygomatic bone on that side and zygomatic bone of the nondefective side of the maxilla were configurated as fixed in all points to skull with zero dislocation. It was submitted that the obturators and maxilla would have completely integrated.

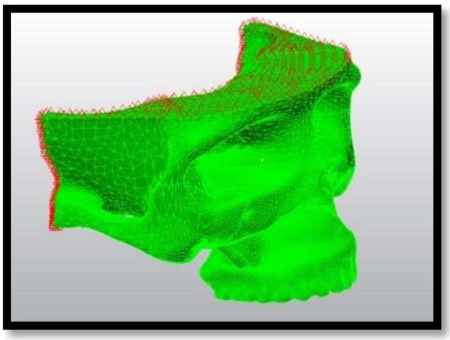
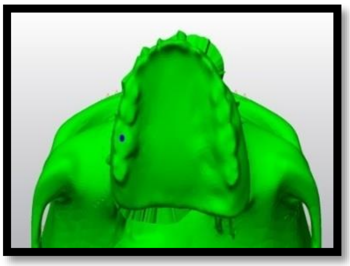


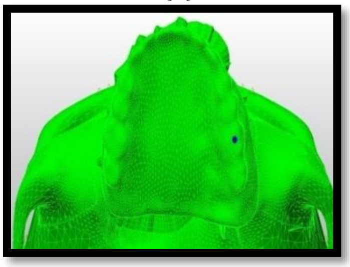
Figure 2. Front views of craniofaci

2.3. Loading

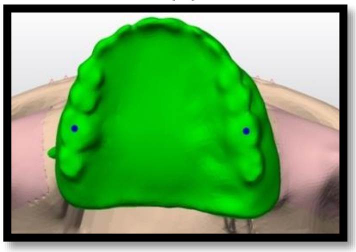
To create clinical situation, loading involved the administration of a simulated bite force as a distributed vertical load of 150 N to the occlusal surfaces of the artificial teeth of the prosthesis. A 150-N vertical load was applied in three different method: first, loading was applied to the defective side; second, to the nondefective side; and third, loading was applied simultaneously to both defective and nondefective sides both loading of the finite element models are shown in Figure 3.



(a)



(b)



(c)

Figure 3. Appearance of the loading on craniofacial model. (a)Occlusal view of the first loading, (b)Occlusal view of the second loading, (c) Occlusal view of the third loadings are shown.

2.4. Material properties

The material properties for the skull, dental and zygomatic implants and bar attachments were recognized to be homogenous and linearly elastic. isotropic, homogeneous, and linearly elastic. The implants used in this study were modeled as a titanium alloy (Ti6Al4V).bar attachments were assumed to be made of pure titanium, and the obturator prosthesis was modeled with a (poly metilmetakrilat) acriylic resin. The mechanical properties of the components of the models in this study were obtained from early literatures. The elastic modulus and Poisson's ratios of the materials used in the analysis are shown in Table 1.

Table 1. Material properties of analysis objects

Material	Young's modulus (E)(MPa)	Poissson's Ratio (v)
Mucosa	680	0,45
Cortical bone	13700	0,3
Ti_6Al_4V	110000	0,3
Acrylic resin(pmma)	2700	0,3
Titanium	115000	0,35
Zygoma	11507	0,3
Matris	2470	0,407
Sinüs	14000	0,3

2.5. Mesh Creation

The geometry was meshed using the Fembro software package. Later meshing the first model consisted of 91.088 nodes and 340.509 elements, the second model consisted of 109.698 nodes and 462.338 elements, the third model consisted of 79.398 nodes and 391.714 elements.

2.6. Maxillary prosthesis models

The 3D finite element analysis model of 3 different types of obturator prostheses was established. The configuration models were as follows;

Model 1 included placement of 1 zygomatic implant on the defected side of the maxilla in combination with 2 dental implant that were placed on the non defected side and completion of the restoration connecting with the fabrication of a rigid bar (Figure 4).

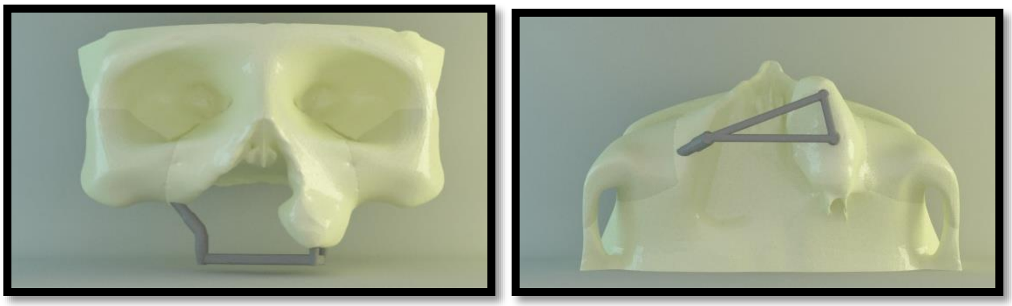


Figure 4. Front and oclusal views of the finite element craniofacial model after maxillectomy of the configuration 1 (model 1): 1 zygomatic implant and 2 dental implant

Model 2 included placement of 2 dental implant on the non defected side of the maxilla and completion of the restoration connecting with the fabrication of a rigid bar (Figure 5).

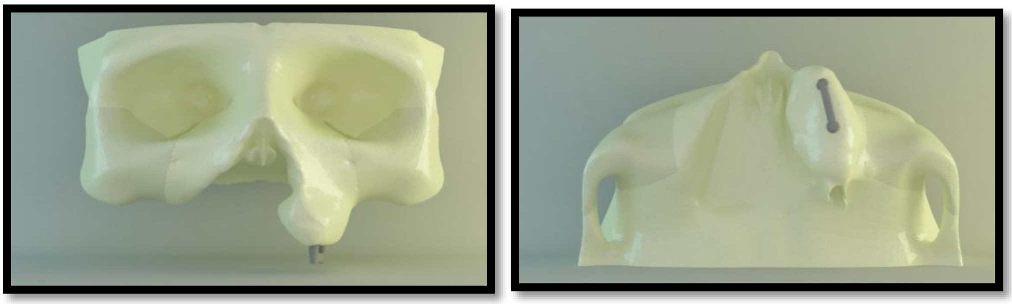


Figure 5. Front and oclusal views of the finite element craniofacial model after maxillectomy of the configuration 2 (model 2): 2 dental implant

Model 3 included placement of 2 zygomatic implant on each side of the maxilla in combination with 1 dental implant that were placed on the non defected side and completion of the restoration connecting with the fabrication of a rigid bar (Figure 6).

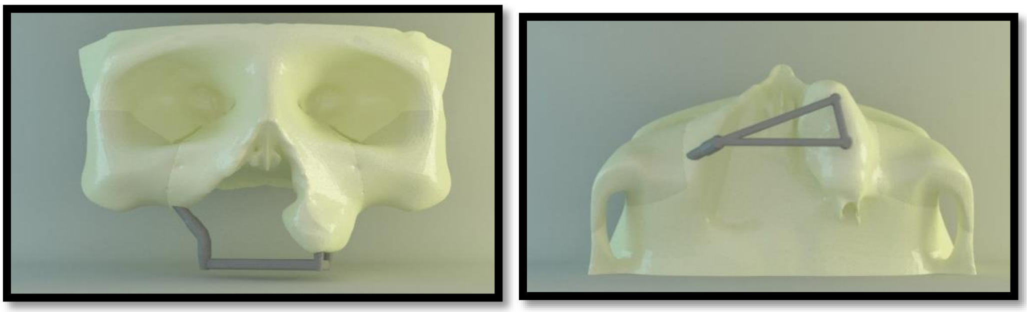


Figure 6 Front and oclusal views of the finite element craniofacial model after maxillectomy of the configuration 3 (model 3): 2 zygomatic implant and one dental implant

3. Results

The results which are depended on a qualitative analysis, in accordance with the degree of maximum principle stress (shown by a color scale) and a quantitative analysis indicated in Mpa.(Figure 7, 8, 9)
Maximum principle stress values of model 1 are shown in figure 7 for the defective side, non defective side and both side loading conditions. In Model 1 the highest maximum principle stresses value was determined in the first and third loading. This highest stress was approved at the zygomatic bone's near the part of the lateral wall and floor of the orbit.

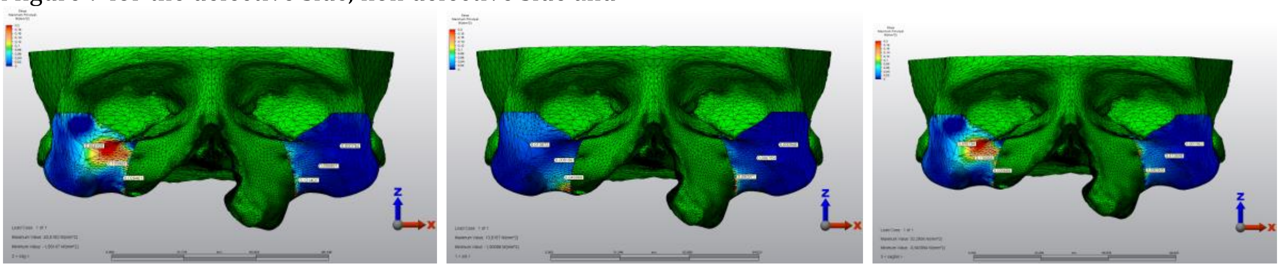


Figure 7. The maximum principle stress distributions in the zygomatic bone under (a) first loading, (b)second loading, and (c) third loading conditions for model 1 (unit: MPa). Colors show level of stress from dark blue (lowest) to red (highest).

Maximum principle stress values of model 2 are shown in figure 8 for the defective side, non defective side and both side loading conditions. In Model 2 the highest maximum principle stresses value was determined in the first and third loading. This highest stress was recorded at the zygomatic bone's maxillary border.

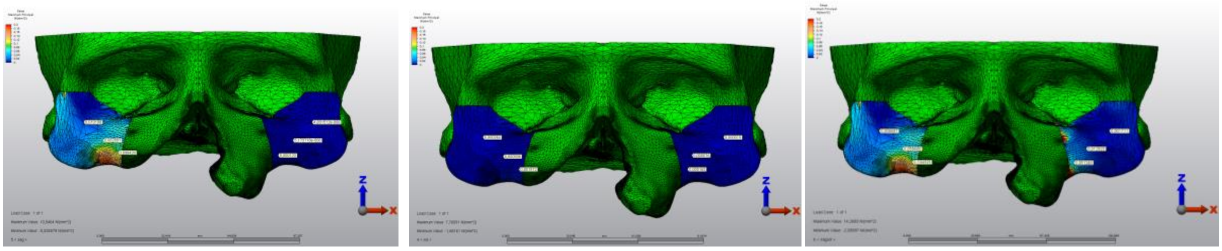


Figure 8. The maximum principle stress distributions in the zygomatic bone under (a) first loading, (b)second loading, and (c) third loading conditions for model 2 (unit: MPa). Colors show level of stress from dark blue (lowest) to red (highest).

Maximum principle stress values of model 3 are shown in figure 9 for the defective side, non defective side and both side loading conditions. In Model 3 the highest maximum principle stresses value was determined in the second and third loading. This highest stress was recorded at the zygomatic bone's near the maxillary and orbital border.

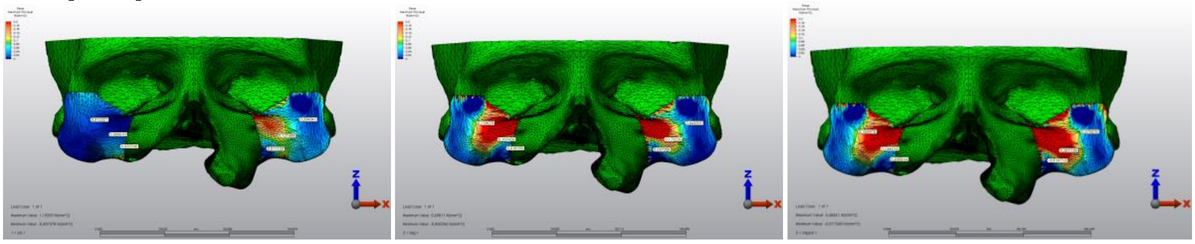


Figure 9. The maximum principle stress distributions in the zygomatic bone under (a) first loading, (b)second loading, and (c) third loading conditions for model 3 (unit: MPa). Colors show level of stress from dark blue (lowest) to red (highest).

4. Discussion and Conclusion

Over the top stress at the implant placed bone is among the potential argument of peri-implant bone loss and failure of osseointegration therefore the estimation of the low level of stress is important for the achievement of the rehabilitation of the implant retained prostheses (Korkmaz et al. 2012, Quaresma et al 2008). A lot of different methods, for instance photoelastic stress analysis, strain gauge analysis and finite element stress analysis have been widely used for stress analysis.(Chun et al 2005) Three dimensional finite element analysis technique has the following advantages; it is non-invasive; the amount of stress experienced at any given point can be theoretically calculated; the material properties of craniofacial structures can be assigned to the nearest one that possibly can simulate this environment *in vitro* unseen sides for example the sinuses can be visualized graphically; the point of application, magnitude and direction of a force may easily be varied to simulate a clinical situation; reproducibility does not affect the physical properties of the material involved; and the study can be repeated as many times as the researcher wishes (Konda and Tarannum 2012).

The use of zygomatic bone for anchorage of long oral implants was originally developed by Branemark et al and first introduced by Aparacio et al for rehabilitation of the atrophied maxillae. (Aparacio et al. 1993) In 1997 Weischer et al cited the use of the zygomatic bone as a support structure in the rehabilitation maxillectomy patients (Weischer et al., 1997).

Kato and colleagues research the internal configuration and the structure of the edentulous zygomatic bone in cadavers using micro-computed tomograph, understanding that the existence of wider and thicker trabeculae at the apical end of the fixture advertises first fixation (Kato et al., 2005). Furthermore, Nkenke et al used calculated tomograph and histomorphometry to search thirthy human zygoma. The study related that the zygomatic bone includes of trabeculer bone unsuitable parameter for implant placement on the other hand the accomplishment of implants placed in the zygomatic bone was terminated by the implant crossing four portions of cortical bone. The portions are; upper border of the zygoma, at the ridge crest, root of the maxillary sinus, the sinus flor (Nkenke et al.,2003).

The use of zygomatic implants is essential to optimize load distribution and to increase prosthesis stability. When compared to a dental implants, the zygomatic implant has an incresaed tendency to bend under horizontal loads. This is corralated; the greatly increased length of zygoma implant and limited bone support in the maxillary alveolar crest (Sudhagar et al., 2011).

Schmidt and colleagues followed a retrospective analysis of patients rehabilated with zygomatic implants on the maxillary resection patients and declared nine cases of particular or all maxillectomies rehabilitated using 28 zygomatic and 10 conventional implants. Nevertheless six zygomatic and three dental implants failed, they confirm that the combination of dental and zygomatic implants could be used in patients with expansive resection of the maxilla (Schimidt et al., 2004). In our study we designed our prosthesis models with zygoma and dental implants together. Conversely we find that use of zygomatic implant with dental implant in the same part of the maxilla increased the stress values of the zygomatic bone. When we use zygomatic and dental implants in different parts of the maxilla it can be acceptable values. Korkmaz et al designed four obturator prosthesis models retained with zygoma and dental implants and mentioned that it had less influence on von mises stress by increasing the number of dental implants of un affected side which was agreement in our results (Korkmaz et al. 2012).

Placement of zygomatic implants should be considered a major surgical procedure and proper training is needed. When compared with major bone grafting it is still less invasive technique and can be used in cases where bone grafts cannot be harvested for any reason (Aparacio and Hatano, 2008).

The distribution of stresses on zygomatic bone were more rational with the support of zygoma implants which can divide the stresses on affected side appropriately, so that it is adequate for the reconstruction of maxillary defects. Maxillary rehabilitation can be further improved by using zygomatic implants.

This is helpful for surgeons, dentists and prosthodontists to make optimal designs of prosthesis in clinical in order to enhance the patients quality of life as much as possible.

Acknowledgements

The authors acknowledge that this research is supported by Gazi University Scientific Research Projects Unit SBE- 03 / 2013-03. The authors would like to thank Ayber Yağız for finite element analysis.

Conflict of Interest

No conflict of interest was declared by the authors.

5. References

Ahila, S.C., Anitha, K.V., Thulasingam, C., 2011. Comparison of obturator design for acquired maxillary defect in completely edentulous patients. Indian Journal of Dental Research, 22, 1, 161-163

Ahmed, B., Hussain, M., Yazdania, N., 2007. A blessing for maxillectomy patients - A case report. Pakistan Oral Dental Journal, 27, 127-8.

Al-Nawas B., Wegener J., Bender C., Wagner W., 2004. Critical soft tissue parameters of the zygomatic implant. Journal of Clinical Periodontol, 31, 497-500

Aparacio, C., Branemark, P-I., Keller, E.E., Olive, J., 1993. Reconstruction of the premaxilla with autogenous iliac bone in combination with osseointegrated. International Journal of Oral Maxillofacial Implants, 8, 61-7

Aparicio, C., Fortes, V., Barluenga, N., 2010. Immediate/ Early Loading of Zygomatic Implants: Clinical Experiences after 2 to 5 years of follow up, Clinical Implant Dentistry and Related Research, 12, 1, 77-82

Aparicio, C., Hatano, N., 2008. The use of zygomatic implants for prosthetic rehabilitation of severely resorbed maxilla. Periodontol 2000, 47, 162-171

Aparicio, C., Quazzani, W., Garcia, R., Arevalo, X., Muela, R., Fortes, W., 2006. A prospective clinical study on titanium implants in the zygomatic arch for prosthetic rehabilitation of the atrophic edentulous maxilla with a follow-up of 6 months to 5 years, Clinical Implant Dentistry Related Research, 8, 114-122

Chun, H.J., Park, D.N., Han, C.H., Heo, S.J., Heo, M.S., Koak, J.Y.,2005. Stress distributions in maxillary bone surroundings overdenture implants with different overdenture attachments. Journal of Oral Rehabilitation, 32, 193–205.

Hu, Y.J., Hardianto, A., Li, S.Y., Zhang, Z.Y., Zhnag, C.P., 2007. Reconstruction of a palatomaxillary defect with vascularized iliac bone combined with a superficial inferior epigastric artery flap and zygomatic implants as anchorage International Journal of Oral and Maxillofacial Surgery, 36, 9,854–857

Kato, Y., Kizu, Y., Tonogi, M., Ide, Y., Yamane., 2005. Internal structure of zygomatic bone related to zygomatic fixture. Journal of Oral Maxillofacial Surgery, 63, 1325-9

Keyf, F., 2001. Obturator prostheses for hemimaxillectomy patients. Journal of Oral Rehabilitation, 28, 821-9.

Konda, P., Tarannum, S.A., 2012. Basic principles of finite element method and its applications in orthodontics. Journal of pharmaceutical and biomedical sciences, 16, 11, 1-5

Korkmaz, F.M., Korkmaz, Y.T., Yaluğ, S., Korkmaz T., 2012. Impact of dental and zygomatic Implants on stres distribution in maxillary defects: A 3 dimensional finite element analysis study, Journal of Oral İmplantology, 5, 557-567

Nkenke, E., Hahn, M., Lell, M., Wiltfang, J., Schultze-Mosgau, S., Stech, B., Radespiel-Tröger, M., Neukam, F.W., 2003. Anatomic site evaluation of the zygomatic bone for dental implant placement, Clinical. Oral Implant. Research, 14, 72–79

Parel, S.M., Brånemark, P.I., Ohrnell, L.O., Svenssond. B., 2001. Remote implant anchorage for the rehabilitation of maxillary defects. Journal of Prosthetic Dentistry, 86, 377-81

Patton, D.W., Ali, A., Davies, R., Fardy, M.J.,1994. Oral rehabilitation and quality of life following the treatment of oral cancer. Dent Update, 21, 231.

Quaresma, S.E., Cury, P.R., Sendyk, W.R., Sendyk, C., 2008. A finite element analysis of two different dental implants: stress distribution in the prosthesis, abutment, implant, and supporting bone. Journal of Oral Implantolgy, 34, 1–6.

Sharma, A.B., Beumer, J., 2005. Reconstruction of maxillary defects: The case for prosthetic rehabilitation. J Oral Maxillofac Surgery, 63, 1770-3.

Schmidt, B.L., Pogrel, M.A., Young, C.W., Sharma, A., 2004. Reconstruction of extensive maxillary defects using zygomaticus implants. Journal of Oral Maxillofacial Surgery,62, 82-9

Sudhagar, J., Ali, S.A., Karthikeyan, S., 2011. Zygomatic İmplants- A Review. JIADS, 2, 2, 24-8

Weischer, T., Schettler, D., Mohr, C.H., 1997. Titanium implants in the zygoma as retaining elements after hemi maxillectomy, International Journal of Oral Maxillofacial Implants, 12, 211-22