Effect of Different Angulations of Peripheral Mini Dental Implants on Stresses Induced On the Crestal Bone (Finite Element Analysis Study)

A Thesis Submitted to the Faculty of Dentistry
Ain-Shams University
In Partial Fulfillment of the Requirements of Master Degree
In Oral and Maxillofacial Prosthodontics

By

Noha Abdel Aziz Hamdy Hassanain
B.D.S, 2005

Faculty of Dentistry
Ain-Shams University
2010

Supervisors

Dr. Ingy A. Talaat

Professor of the Prosthodontics and Chairman of

Prosthodontics Department,

Faculty of Dentistry, Ain-Shams University

Dr. Rami M. Ghali

Lecturer of Prosthodontics

Prosthodontics Department,

Faculty of Dentistry, Ain-Shams University

بسم الله الرحمن الرحيم

{قالوا سبحانك لا علم لنا إلا ما
أنت العليم الحكيم} علمتنا إنك

أية 32 من سورة البقرة

Dedication

To my Father's Soul

To my Great Mother

To my lovely Husband & Daughter

To my Sweet Sister & my Dear Brother

Acknowledgement

First of all I would like to thank ***Allah*** who paved the way and give me the ability to accomplish this work.

I am greatly honored to express my deepest gratitude to Prof. ***Dr. Ingy Amin Talaat***, ***Professor of Prosthodontics, Faculty of Dentistry, Ain-Shams University*** for her valuable guidance and effort throughout my academic and clinical work and for her inspiration encouragement which undoubtedly made this work possible.

I am extremely grateful to ***Dr. Rmay Maher Ghali, Lecturer of Prosthodontics,*** for his sincere help and cooperation during this study.

I would like to express my heartfelt thanks and sincere appreciation to ***Dr. Ahmed El Ragi, Lecturer of Civil Engineering, Fayoum University,*** for his support, generous help and guidance. I owe him all that I learned in the field of finite element analysis.

My deep appreciation to ***all the staff & members of the Proshodontics Department, Faculty of dentistry, Ain-Shams University*** for their valuable help and cooperation.

My special thanks to my understanding ***husband*** for his loyal help, support, encouragement and his insistence to accomplish this work.

My deeply and hearty acknowledgement to ***all my family members*** whom really supported me and made it possible to work up this work.

Contents

Contents i

List of Figures iii

List of Tables: vii

I) Mandibular complete overdenture: 3

A) Problems with conventional complete denture: 3

B) Implant mandibular overdenture: 4

II) Mini dental implants: 26

III) Computer tomography scanning: 34

1- Computed tomography: 34

2- Multislice scanning: 34

3- Application of CT in implant dentistry: 36

IV) Stress analysis methods: 37

1- Electrical resistance strain gauge: 37

2- Photoelastic stress analysis: 38

3- Holographic interferrometry: 39

4- Finite element analysis: 40

Numerical Model Construction: 52

A) Multislice Computed Tomography Scanning: 52

1- Data Acquisition: 53

2- Technical Consideration: 53

3- Image Processing: 54

4- Display and Storage: 54

B) Geometric Three Dimension Reconstruction: 54
1- Importing images: 54
2- Thresholding: 55
3- Editing: 57
4- Calculating the 3D model: 57
5- Remeshing: 58
6- Exporting: 60
C) Finite Element Analysis: 60
1- Preprocessing: 61
2- Processing: 72
3- Postprocessing: 74
I) Stresses: 78
1- Stresses induced on the peripheral implants: 79
2- Stresses induced on the central implants: 94
3- Stresses induced on the bone surrounding peripheral implants: 100
4- Stresses induced on the bone surrounding central implants: 106
II) Displacement: 114
III) Load distribution on the mini implants: 118
I) Discussion of the materials and methods: 122
II) Discussion of the results: 130

List of Figures

FIGURE 1: 3D MODEL OF COMPLETELY EDENTULOUS MANDIBLE AND COMPLETE DENTURE 49
FIGURE 2: FOUR PARALLEL IMPLANTS AND PERPENDICULAR TO THE HORIZONTAL PLANE........................... 50
FIGURE 3: PERIPHERAL IMPLANTS WITH10 DEGREES MESIAL ANGULATIONS 51
FIGURE 4: PERIPHERAL IMPLANTS WITH10° DISTAL ANGULATIONS.. 51
FIGURE 5: CT MACHINE 52
FIGURE 6: ACQUISITION UNIT.. 53
FIGURE 7: 3D MODEL OF THE EDENTULOUS MANDIBLE SHOWN IN CORONAL, AXIAL, SAGITTAL, AND 3D VIEW 55
FIGURE 8: DENTURE MASK 56
FIGURE 9: CORONAL, SAGITTAL, AND AXIAL SECTIONS SHOWING THE BONE MASK 56
FIGURE 10: 3D MODEL OF MANDIBLE AND DENTURE 57
FIGURE 11: MANDIBLE REMESH 58
FIGURE 12: REMESHED MANDIBLE AND DENTURE 58
FIGURE 13, A.B: A) MANDIBLE BEFORE SMOOTHING, B) MANDIBLE AFTER SMOOTHING........................ 59
FIGURE 14, A.B: SAGITTAL AND FRONTAL VIEW DENTURE AND MANDIBLE AFTER SMOOTHING 60
FIGURE 15: GEOMETRY OF MANDIBULAR ALVEOLAR BONE 62
FIGURE 16: GEOMETRY OF MUCOSA 62
FIGURE 17: GEOMETRY OF DENTURE.. 63
FIGURE 18: GEOMETRY OF ALVEOLAR BONE, MUCOSA AND DENTURE 63
FIGURE 19: MEASURING THE INTERFORAMINAL DISTANCE 64
FIGURE 20: DISTRIBUTING THE MINI IMPLANTS EQUIDISTANT IN THE INTERFORAMINAL REGION................. 65
FIGURE 21: MODE I "FOUR PARALLEL VERTICAL MINI IMPLANTS" 65
FIGURE 22: PERIPHERAL IMPLANTS WITH 10 DEGREES MESIAL ANGULATIONS AND ITS DIRECTION IN BONE .. 66
FIGURE 23: PERIPHERAL MINI IMPLANTS WITH 10 DEGREES DISTAL ANGULATIONS AND ITS DIRECTION IN BONE 66
FIGURE 24: LATERAL SECTION SHOWING THE DENTURE, MUCOSA, TRABECULAR AND COMPACT BONE 67
FIGURE 25: AXIAL SECTION SHOWING DENTURE, MUCOSA, CANCELLOUS, AND COMPACT BONE AND BONE IMPLANT INTERFACE 68
FIGURE 26: MANDIBULAR ALVEOLAR BONE AND OVERDENTURE MESH 70
FIGURE 27: MUCOSA AND MINI IMPLANT MESH 71
FIGURE 28: UNILATERAL LOAD APPLICATION AT THE JUNCTION OF LOWER FIRST MOLAR AND LOWER SECOND PREMOLAR "VERTICAL CASE" 71
FIGURE 29: SUPPORT AT THE MANDIBULAR CONDYLE "FRONTAL AND LATERAL...................................... 72
FIGURE 30: DIAGRAM SHOWING THE RELATION BETWEEN FORCE, DISPLACEMENT, STRESS, AND STRAIN...... 74
FIGURE 31: REPRESENTING THE NODE AND THE THREE STRESSES ACTING ON EACH FACE 75
FIGURE 32: REPRESENTING THE NORMAL AND SHEAR STRESSES ACTED ON A NODE. ANGLE BETWEEN NORMAL AND SHEAR STRESS IN TRUTH IS 90^{o} WHICH WAS ½ THE ANGLE IN MOHR CIRCLE. 76
FIGURE 33: REPRESENTING 3D MOHR CIRCLE OF DIAMETER S_1S_3, AND MAX. SHEAR STRESS REPRESENTED AS $(S_1S_3)/2$, I.E. ½ THE DIAMETER.. 77
FIGURE 34: STRESSES INDUCED IN PERIPHERAL IMPLANT DURING BILATERAL LOADING 81

Figure 35: Stresses induced in peripheral implant during unilateral loading 81
Figure 36: S_{EQV} stress in the whole complex in Model I during bilateral loading 82
Figure 37: S_{EQV} stress in the four MDI's in Model I during bilateral loading 82
Figure 38: S_{EQV} stress in Model I during bilateral loading 82
Figure 39: S3 stress in the whole complex in Model I during bilateral loading 83
Figure 40: S3 stress in the 4 MDI's in Model I during bilateral loading 83
Figure 41: S3 stress in Model I during bilateral loading 83
Figure 42: S_{INT} Stress in the whole complex in Model I during bilateral loading 84
Figure 43: S_{INT} Stress in the 4 MDI's in Model I during bilateral loading 84
Figure 44: S_{INT} Stress in Model I during bilateral loading 84
Figure 45: S_{EQV} stress in the whole complex in Model I during unilateral loading 85
Figure 46: SEQV stress in the four MDI's in Model I during unilateral loading 85
Figure 47: S_{EQV} stress in Model I during unilateral loading 85
Figure 48: S3 stress in the whole complex in Model I during unilateral loading 86
Figure 49: S3 stress in the 4 MDI's in Model I during unilateral loading 86
Figure 50: S3 stress in Model I during unilateral loading 86
Figure 51: S_{INT} stress in Model I during unilateral Loading 87
Figure 52: S_{INT} stress in the 4 MDI's in Model I during unilateral loading 87
Figure 53: S_{INT} stress in Model I during unilateral loading 87
Figure 54: S1 stress in Model II during bilateral loading 89
Figure 55: S1 stress on the four MDI's in Model II during bilateral loading 89
Figure 56: S1 stress in Model II during bilateral loading 89
Figure 57: S_{EQV} Stress in Model II during bilateral loading 90
Figure 58: S_{EQV} stress on four MDI's in Model II during bilateral loading 90
Figure 59: S_{EQV} stress in Model II during bilateral loading 90
Figure 60: S_{EQV} Stress in Model II during unilateral loading 91
Figure 61: S_{EQV} stress on four MDI's in Model II during unilateral load 91
Figure 62: S_{EQV} stress in Model II during unilateral loading 91
Figure 63: S3 Stress in Model II during unilateral loading 92
Figure 64: S3 stress in the four MDI's in Model II during unilateral loading 92
Figure 65: S3 stress in Model II during unilateral loading 92
Figure 66: S_{EQV} stress in Model III during bilateral loading 93
Figure 67: S_{EQV} stress in Model II during unilateral loading 93
Figure 68: Stresses induced in central implant during bilateral loading 95
Figure 69: stresses induced in frontal implant during unilateral loading 95
Figure 70: S_{EQV} stress in Model I during bilateral loading 96
Figure 71: S_{EQV} stress in Model I during bilateral loading 96
Figure 72: S1 stress in Model II during bilateral loading 97
Figure 73: S_{EQV} stress in Model II during bilateral loading 97
Figure 74: S_{EQV} stress in Model II during unilateral loading 98
Figure 75: S_{EQV} stress in Model III during bilateral loading 98

FIGURE 76: S_{EQV} STRESS ON FOUR MDI'S IN MODEL III DURING BILATERAL LOADING 99
FIGURE 77: S_{EQV} STRESS IN MODEL III DURING BILATERAL LOADING 99
FIGURE 78: S_{EQV} STRESS MODEL III DURING UNILATERAL LOADING 99
FIGURE 79: STRESSES INDUCED IN BONE SURROUNDING PERIPHERAL IMPLANT DURING BILATERAL LOADING 101
FIGURE 80: STRESSES INDUCED IN BONE SURROUNDING PERIPHERAL IMPLANT DURING UNILATERAL LOADING 101
FIGURE 81: SEQV STRESS IN MODEL I DURING BILATERAL LOADING 102
FIGURE 82: S_{EQV} STRESS IN MODEL I DURING BILATERAL LOADING 102
FIGURE 83:S1 STRESS IN MODEL II DURING BILATERAL LOADING 103
FIGURE 84: LONGITUDINAL SECTION SHOWING HIGHER S1 STRESS AT CERVICAL REGION THAN APICAL REGION IN MODEL II DURING BILATERAL LOADING 103
FIGURE 85: S_{EQV} STRESS IN MODEL II DURING BILATERAL LOADING 103
FIGURE 86: LONGITUDINAL SECTION SHOWING HIGHER S_{EQV} STRESS AT CERVICAL REGION THAN APICAL REGION IN MODEL II DURING BILATERAL LOADING 104
FIGURE 87: S_{EQV} STRESS IN MODEL II DURING UNILATERAL LOADING 104
FIGURE 88: LONGITUDINAL SECTION SHOWING HIGHER S_{EQV} STRESS AT CERVICAL REGION THAN APICAL REGION IN MODEL II DURING UNILATERAL LOADING 104
FIGURE 89: S_{EQV} STRESS IN MODEL III DURING BILATERAL LOADING 105
FIGURE 90: LONGITUDINAL SECTION SHOWING HIGHER S_{EQV} STRESS AT CERVICAL REGION THAN APICAL REGION IN MODEL III DURING BILATERAL LOADING 106
FIGURE 91: S_{Eqv} STRESS IN MODEL III DURING UNILATERAL LOADING 106
FIGURE 92: STRESSES INDUCED IN THE BONE SURROUNDING THE CENTRAL IMPLANT DURING BILATERAL LOADING 108
FIGURE 93: STRESSES INDUCED IN THE BONE SURROUNDING THE CENTRAL IMPLANT DURING UNILATERAL LOADING 108
FIGURE 94: S_{EQV} STRESS IN MODEL I DURING BILATERAL LOAD 109
FIGURE 95: S_{EQV} STRESS IN MODEL I DURING UNILATERAL LOAD 109
FIGURE 96: S1 STRESS IN MODEL II DURING BILATERAL LOADING 110
FIGURE 97: LONGITUDINAL SECTION SHOWING HIGHER S1 STRESS AT CERVICAL REGION THAN APICAL REGION IN MODEL II DURING BILATERAL LOADING 110
FIGURE 98: S_{EQV} STRESS IN MODEL II DURING BILATERAL LOADING 111
FIGURE 99 : LONGITUDINAL SECTION SHOWING HIGHER S_{EQV} STRESS AT CERVICAL REGION THAN APICAL REGION IN MODEL II DURING BILATERAL LOADING 111
FIGURE 100: S1 STRESS IN MODEL II DURING UNILATERAL LOADING 111
FIGURE 101: LONGITUDINAL SECTION SHOWING HIGHER S_{EQV} STRESS AT CERVICAL REGION THAN APICAL REGION IN MODEL II DURING UNILATERAL LOADING 112
FIGURE 102: S_{EQV} STRESS IN MODEL II DURING UNILATERAL LOADING 112
FIGURE 103: S_{Eqv} STRESS IN MODEL III DURING BILATERAL LOADING 113
FIGURE 104: S_{EQV} STRESS IN MODEL III DURING UNILATERAL LOADING 113
FIGURE 105: DISPLACEMENT OF PERIPHERAL IMPLANT DURING BILATERAL LOADING 114

FIGURE 106: DISPLACEMENT OF PERIPHERAL IMPLANT DURING UNILATERAL LOADING 115
FIGURE 107: DISPLACEMENT OF BONE SURROUNDING PERIPHERAL IMPLANT DURING BILATERAL LOADING 115
FIGURE 108: DISPLACEMENT OF BONE SURROUNDING PERIPHERAL IMPLANT DURING UNILATERAL LOADING 115
FIGURE 109: UX IN MODEL I DURING BILATERAL LOADING 116
FIGURE 110: UY IN MODEL II DURING BILATERAL LOADING 116
FIGURE 111: UZ IN PERIPHERAL IMPLANT IN MODEL III DURING BILATERAL LOADING 116
FIGURE 112: UZ IN MODEL I DURING UNILATERAL LOADING 117
FIGURE 113: UX IN MODEL II DURING UNILATERAL LOADING 117
FIGURE 114: UY IN MODEL III DURING UNILATERAL LOADING 117
FIGURE 115: BILATERAL AND UNILATERAL LOAD DISTRIBUTION IN MODEL I 119
FIGURE 116: BILATERAL AND UNILATERAL DISTRIBUTION IN MODEL II 119
FIGURE 117: BILATERAL AND UNILATERAL LOAD DISTRIBUTION IN MODEL III 119
FIGURE 118: BILATERAL LOAD DISTRIBUTION IN DIRECTION Z 120
FIGURE 119: PERCENTAGE OF CHANGE OF LOAD 'BILATERAL IN TILTED MDIS IN RELATION TO VERTICAL MDI 120
FIGURE 120: UNILATERAL LOAD DISTRIBUTION IN DIRECTION Z 121
FIGURE 121: PERCENTAGE OF CHANGE OF LOAD "UNILATERAL" IN TILTED MDIS IN RELATION TO VERTICAL MDIS 121

List of Tables:

TABLE 1: SCANNING PARAMETERS 53
TABLE 2: MATERIAL PROPERTIES 69
TABLE 3: NUMBER OF NODES AND ELEMENTS 70
TABLE 4: STRESSES INDUCED ON PERIPHERAL IMPLANTS DURING BILATERAL LOADING 80
TABLE 5: STRESSES INDUCED ON PERIPHERAL IMPLANTS DURING UNILATERAL LOADING 80
TABLE 6: STRESSES INDUCED ON CENTRAL IMPLANT DURING BILATERAL LOADING 94
TABLE 7: STRESSES INDUCED ON CENTRAL IMPLANT DURING UNILATERAL LOADING 94
TABLE 8: STRESSES INDUCED ON BONE SURROUNDING PERIPHERAL IMPLANT DURING BILATERAL LOADING 100
TABLE 9: STRESSES INDUCED ON BONE SURROUNDING PERIPHERAL IMPLANT DURING BILATERAL LOADING 100
TABLE 10: STRESSES INDUCED ON THE BONE SURROUNDING CENTRAL IMPLANT DURING BILATERAL LOADING 107
TABLE 11: STRESSES INDUCED ON THE BONE SURROUNDING CENTRAL IMPLANT DURING UNILATERAL LOADING 107

Introduction

The most oral dramatic changes have been reported in completely edentulous patients with atrophic mandible and/or maxilla. In cases in which retention of the denture is extremely difficult or impossible, the placement of implants that retain and support an overdenture, allows for optimal results with regard to patient satisfaction and function. [1,2]

Furthermore, the continuous bone loss after tooth loss and associated compromises in esthetics, function, and health make most of the edentulous patients are implant candidates. [3]

The successful prosthetic outcome of the implant retained overdenture has such a high impact on the academic and clinical community in which the implant authorities suggested that the prosthetic rehabilitation with conventional denture of patients with completely edentulous mandible should no longer be the treatment of the choice. Instead, the placement of implants and the fabrication of the implant retained overdenture should be the option to consider first. [2-5]

Successful oral rehabilitation with mini implants for partially or fully edentulous patients has been reported. Provisional mini dental implants provide immediate overdenture or fixed prosthesis support after final implant placement. This technique requires minimal additional time and is economic because the patients' old dentures are used as immediate temporary prostheses. The most effective use of mini implants is its placement in narrow bucco-lingual bone width. These mini implants permits the reestablishment of function and esthetics in the rehabilitated of totally or partially edentulous patients. [6,7]

It has been suggested that implants should be positioned parallel to the path of insertion of planned prostheses and as perpendicular to the occlusal plane as possible to ensure axial loading and to minimize the production of bending moments. [8]

Nowadays a shift in the concept of parallel, vertical implant placement is taking place. Intentional tilted implant placement is now described to provide simpler less invasive solutions in situations that would otherwise require bone augmentation, nerve trans-positioning or sinus elevation.

Tilting of the fixture may lead to better anchorage and/ or better implant position [9]. The installation of implant with tilt has been widely accepted in the treatment in prosthesis supported by implants. However, little information exists about the biomechanical effect and the influence of tilted implant placement on bone stress distribution in the oral rehabilitation of patients with mini implants.

Review of literature

I) Mandibular complete overdenture:

Mandibular complete overdenture treatment uses a removable complete denture that overlies retained teeth, tooth roots, or dental implants. [1]

A) Problems with conventional complete denture:

Redford et al [10] demonstrated that more than 50% of conventional mandibular complete dentures have problems with retention and stability and that mandibular complete denture produced significantly more patient problems than maxillary dentures, primarily because of poor prosthesis retention. [1]

Maintaining alveolar bone in a preventative fashion before the resorption process occurs is an important consideration for denture treatment outcome. After residual ridge resorption occurs, few treatment options are available for reestablishing the supporting tissue volume for dentures. These options include alveolar ridge augmentation using natural and synthetic materials, tissue extension procedures for exposing additional intraoral tissues, repositioning muscle attachments, and finally implant insertion. Unfortunately, these procedures have demonstrated mixed long-term success that can significantly increase treatment costs, and have occasionally introduced significant complications and morbidity. [11]