STRESS DISTRIBUTION WITH DIFFERENT ANGULATION OF IMPLANT WITH OR WITHOUT CANTILEVER EXTENSION: A SYSTEMATIC REVIEW

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Abstract

Title: Stress Distribution with Different Angulation of Implant with Or Without Cantilever Extension: A Systematic Review

Introduction: To systematically review the literature on stress distribution of implants with different angulation and the effect of cantilever prosthesis.

Study Design: The three major electronic databases were screened: MEDLINE (via PubMed), and SCOPUS and ELSEVIER

Review: Methodological quality assessment showed sample size calculation to be reported by only one study, and follow-up did not include a large number of participants - a fact that may introduce bias and lead to misleading interpretations of the study results.

Conclusions: A systematic review of the current literature showed only in vitro evidence that there is no consensus on the advantage of using an offset configuration implant compared to those in straight-line configuration, well some studies shown significant improvement of bone stress distribution when an angulated implant is under oblique loading.

Keywords: Dental implants, implant-retained dental Prosthesis, prosthodontics, biomechanics.

INTRODUCTION

Implant supported prosthesis has become a routine dental treatment. To achieve the best outcome, careful consideration of technical and biomechanical parameters, is essential[¹]. The rehabilitation of the posterior region of the jaw is complex, mainly due to greater masticatory forces when compared with the anterior region. In this region, implants used to retain the three-element prostheses are normally placed in a straight line. It has been reported that the role of implant length is more significant in reducing bone stress and improving the implant-abutment stability in comparison with implant diameter.[²,³] Nevertheless, a small displacement of the central implant to the buccal or lingual area has been suggested, featuring an offset configuration, whose purpose, theoretically, is a stress distribution more favorable to prosthetic components, implant, and bone.
Distal cantilevers have been discussed in fixed prosthodontics as a method to re-establish occlusion when there are no posterior teeth to support a prosthesis. Extrapolation of the findings in natural dentition toward implant dentistry has lead to considerable debate within the dental implant community. According to Misch, under ideal conditions, the distal cantilever should not extend 2.5 times the A-P spread. Parafuction, crown height, masticatory dynamics, gender, age, and arch location will determine the magnitude and direction of force. While, number of implants, width, length, design, and bone density will determine the functional surface area. [4]

There are various implant dentistry treatment concepts using distal cantilever prosthesis with reports of long-term success.

Some of the reasons for incorporating the distal cantilever design in implant supported prostheses include a reduction in the number of implants used to support a prosthesis, which also has a concomitant reduction in the cost of the restorations; a decreased need for surgical intervention; and a simplification of surgery in those anatomical areas that are associated with the inferior alveolar nerve vascular bundle or the sinus floor. When planning a distal cantilever, factors such as abutment selection, control of the magnitude of forces, and rigidity/strength of connectors are not fully understood.

Methods of restoring tissues are very complicated and difficult; meanwhile several studies have described the advantages of rebuilding the function through cantilever fixed pros thesis [5,6] which resulted in high application of cantilever in implant supported fixed pros thesis. Since the impact of a cantilever is similar to a force being exerted by an class I lever [7,8], biomechanical force in implant supported prosthesis might jeopardize the health of its supporting bone [9].

Materials and methods

Procedure

The studies based on inclusion and exclusion criteria, analyzing and including all potentially eligible studies. All abstracts and full texts were reviewed. No authors were contacted. Disagreements among the authors were assessed, The study standard was the criteria for a systematic review proposed by the PRISMA (Preferred Reporting Items for Systematic reviews). The PRISMA statement consists of a 27-item checklist and a four-phase flow diagram. Its aim is to help authors improve the reporting of systematic reviews and meta-analyses.

Search strategy

Independent reviewer conducted a search on PubMed/Google scholar, for studies published in English, from January 1, 2007 to January 17, 2020. The keywords used were “angle” and “dental implant,” and search details were: angle [All Fields] AND (“dental implants” [MeSH Terms] OR (“dental” [All Fields] AND “implants” [All Fields]) OR “dental implants” [All Fields] OR (“dental” [All Fields] AND “implant” [All Fields]) OR “dental implant” [All Fields]). To avoid bias in the search strategy.

The following keywords were used: “angle” and “stress distribution,” “angle” and “bone,” “cantilever” and “jaw,” “angle” and “maxilla,” “angle” and “mandible,” “angle” and “dental implant,” “angle” and “stress distribution,” “angle” and “bone,” “angle” and “jaw,” “angle” and “maxilla,” “angle” and “mandible,” “cantilever and “dental implant,” “cantilever” and “stress distribution,” “cantilever” and “bone,” “cantilever” and “jaw,” “cantilever” and
“maxilla,” “cantilever” and “mandible,” “angle” and “prostheses,” “angle” and “prostheses,” “cantilever” and “prostheses,” and “angulation.”

Criteria for selection of studies

Initially, the selection of studies focused on analyzing the title and abstract and computer simulations were considered eligible studies were analyzed and included in the sample. Thus, population, intervention, comparison, and outcome (PICO), as recommended by the PRISMA statement, were determined as questioning criteria to organize an objective clinical question and an appropriate inclusion focus. \[^{[10,11]}\]

**Population:** Experiments that performed studies with osseointegrated dental implants;

**Intervention:** Implant placement in different angulation

**Comparison:** Implants with different angulation with cantilever or without cantilever extension

**Outcome:** Possible differences between the positions on bone stress distribution.

The PICO question was structured as follows:

What is the effect of different angulation of implant configuration with or without cantilever extension?

Inclusion criteria

After the initial search, inclusion criteria were: studies that related the different implant angulation and cantilever length in computer simulation finite element analysis published in English.

Exclusion criteria

The exclusion criteria were: studies unrelated to angulation and single implant placement, duplicated studies, studies not published in English.

Quality assessment

The assessment of methodology quality was based on the PRISMA statement.

Data analysis

Data were obtained similarly from all included studies, in this order: first author, year, type of study, implant used in the study, location of the implant placed, type of the bone, diameter, length, angulation, and arch jaw.
Results

General outcomes

A total of HUNDRED titles were identified with the initial search. SIX were selected based on title and abstract.

<table>
<thead>
<tr>
<th>STUDIES</th>
<th>UNCLEAR</th>
<th>MODERATE</th>
<th>HIGH</th>
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<tbody>
<tr>
<td>A. Fazel et al</td>
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<td>Marco Bevilacqua et al</td>
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<td>Ebadian Behnaz et al</td>
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<td>Fariba Saleh Saber et al</td>
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<td>Mostafa Pirmoradian et al</td>
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<td>Anju Kumari et al</td>
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</table>

The quality of the studies had MODERATE Risk Of BIAS suggesting appropriate methodological process of the study.

TOOL FOR RISK OF BIAS

All the included studies are comparative studies so the GRACE TOOL was used to evaluate the quality of the studies.

GRACE TOOL : Good Research For Comparative Effectiveness.

3D FEA

Three-dimensional finite element stress analysis is a numeric simulation determining stress and displacements via models of geometrically complex structures like dental implants. This model allows simulated force application to specific points in the system, and provides the resultant forces in the surrounding structures.

This form of study uses qualitative data to find that the main advantage of offset configuration implants is better stress distribution to bone tissue, especially against oblique loading (horizontal), but, in axial load...
application and regarding stress distribution, no advantage was observed in the use of offset implants. Studies mostly used implants angulation as zero degrees (0) to forty five degrees (45)

**PRISMA FLOW DIAGRAM**

- **Record identified through search engines**
  - Pubmed: 60
  - Scopus: 25
  - Elsevier: 15

- **Hand searches**: 0

- **Total title and abstract read**: 100

- **Record screened**: 31

- **Excluded on the basis of title and abstract**: 69

- **Full text articles read after assessing eligibility**: 10

- **Duplicate articles extracted**: 21

- **Articles excluded as parameter other than angle, length cantilever**: 4

- **Articles included for qualitative analysis**: 6
Discussion

With the advent of the Brånemark approach utilizing complete-arch implant-supported cantilever prostheses, the distal cantilever has gained acceptance in implant dentistry. Technical complications such as fracture of the acrylic resin teeth and prosthesis base were causes for failures for mandibular fixed implant supported rehabilitations with distal cantilevers.

Some authors attempted to summarize the causes of failures/complications of implants in association with distal cantilevers. Insufficient metal thickness, inferior solder joints, parafunctional habits of patients, incorrect framework design, excessive cantilever length, and inadequate strength of alloys have all been reported as causes of prosthesis failure.

In some studies the results showed that stress declined around the cervical area of posterior implants in cancellous and cortical bone as the angle increased and spread distally along crestal bone.

In other words, the more vertical are the posterior implants and the longer the cantilever prosthesis, the higher and concentrated becomes the von Mises stress.

Data summary of the articles selected

<table>
<thead>
<tr>
<th>STUDY ID</th>
<th>SAMPLE SIZE</th>
<th>IMPLANT USED IN THE STUDY</th>
<th>LOCATION OF IMPLANT PLACED</th>
<th>TYPE OF BONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fazel et al 2007[12]</td>
<td>One hundred and fifty nine patients who were treated by 482 implants supported fixed partial prosthesis with and without cantilever after at least four years of treatment.</td>
<td>ITI and Branemark implant</td>
<td>maxilla and mandible</td>
<td>marginal bone</td>
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<tr>
<td>Marco Bevilacqua eT al 2011[13]</td>
<td>4 models Inclination and {cantilever extensions} 1. 0 degree - 13 mm 2. 15 degree - 9mm 3. 30 degree- 5 mm 4.45 degree- 0 mm</td>
<td>Four, 4-mm-diameter, cylindrical screw type implants with smooth apices (Biomet 3i, Palm Beach Gardens)</td>
<td>pre-maxilla</td>
<td>cancellous and cortical bone</td>
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<tr>
<td>Authors</td>
<td>Models</td>
<td>Implant System</td>
<td>Bone Type</td>
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<tr>
<td>Ebadian Behnaz et al</td>
<td>3 MODELS</td>
<td>Biohorizons Internal, Implant system Inc., Birmingham, Al, USA</td>
<td>Cortical bone</td>
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<td></td>
<td>MODEL 1: Both implants, parallel to adjacent teeth, with straight abutments</td>
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<td></td>
<td>MODEL 2: Anterior implant with 15 mesial angulations and posterior implant were placed parallel to adjacent tooth</td>
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<td></td>
<td>MODEL 3: Both implants with 15 mesial angulations and parallel to each other with 15° angulated abutments</td>
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<tr>
<td>Fariba Saleh Saber et al</td>
<td>5 MODELS</td>
<td>Nobel Biocare</td>
<td>Cortical Bone</td>
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<td></td>
<td>distal implants inclined</td>
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<td>1MODEL - 0degrees</td>
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<td>2MODEL 15degrees</td>
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<td></td>
<td>3MODEL - 30degrees</td>
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<td>4MODEL - 45degrees</td>
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<td></td>
<td>5 MODELS - , six vertical implants were placed</td>
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<tr>
<td>Mostafa Pirmoradian et al</td>
<td>Three dimensional FE models of implant-abutment, cortical bone and cancellous bone are created by considering a variation of 0.6 mm to 1 mm on threads pitch while the implant lengths range from 8.5 mm to 13 mm.</td>
<td></td>
<td>Mandible</td>
<td>Cortical bones, and cancellous bones</td>
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<tr>
<td>Anju Kumari et al</td>
<td>Three different configurations, corresponding to 3 tilt degrees of the distal implants (30°, 40°, and 45°) were subjected to 4 loading simulations. (4 mm, 8 mm, 12 mm, 16 mm)</td>
<td></td>
<td>Edentulous maxilla</td>
<td>Cortical bone Cancellous bone</td>
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</tbody>
</table>
## Summary of each study

<table>
<thead>
<tr>
<th>STUDY</th>
<th>SUMMARY</th>
<th>MODEL</th>
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<tbody>
<tr>
<td>A. Fazel et al 2007</td>
<td>The cantilever design has a significant influence on stress distribution in implant and its supporting tissues and can lead to unfavorable biomechanical effects around them. Furthermore, finite element studies revealed that higher stress concentrations developed in models with cantilever prostheses.</td>
<td>3D FEA</td>
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<tr>
<td>Marco Bevilacqua et al 2011</td>
<td>The maximum stress values recorded in compact bone for the vertical implants were 75.0 MPa for the distal implants and 35.0 MPa for the mesial implants. The maximum stresses for the 45-degree tilted distal implants were reduced to 19.9 MPa for the distal implants and 7.8 MPa for the mesial implants. Maximum stress values for vertical implants in cancellous bone were 68.6 MPa for distal implants and 30.0 MPa for mesial implants. The use of distal tilted implants results in a reduction in stresses in the periimplant bone and in metal frameworks secondary to cantilever length reduction and implant length increase.</td>
<td>3D FEA</td>
</tr>
<tr>
<td>Ebadian Behnaz et al 2015</td>
<td>Maximum stress values in splinted restorations of straight abutments (model 1) were lower than nonsplinted restorations (model 2). Maximum stress values in the straight implant body (130.4 Mpa) and it is surrounded cortical bone in premolar site (57.93) were more than other sites and another models. In third model maximum stress value of cortical bone around angulated premolar implant in splinted simulation was more than straight position (21.41 Mpa)</td>
<td>3D FEA</td>
</tr>
<tr>
<td>Fariba Saleh Saber et al 2015</td>
<td>MODEL 1: The maximum von Mises stress is 51.69 MPa. MODEL 2: The maximum von Mises stress is 46 MPa. MODEL 3: The maximum Von Mises stress is 33.24 MPa. MODEL 4: The maximum von miss stress is 20 MPa. MODEL 5: The maximum von miss stress is 19.89 MPa.</td>
<td>3D FEA</td>
</tr>
<tr>
<td>Mostafa Pirmoradian et al 2019</td>
<td>Significant correlation can be observed between maximum von Mises stress in cancellous bone, cortical bone, and implant-abutment the cancellous bone, cortical bone, and implant-abutment, the lowest von Mises stresses occur when the ratio of threads pitch to length is between 0.05 to 0.07.</td>
<td>3D FEA</td>
</tr>
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</table>
CONCLUSION:

A systematic review of the current literature showed only finite element analysis evidence that there is advantage of using an angulated configuration implant compared to those in straight-line configuration. After a systematic review of the literature and a traditional literature review, it can be concluded that, based upon the use of distally tilted, number of implants, length of the implant, or with the cantilever or without cantilever support.

The stress declined in both cancellous and cortical bones but the reduction is only significant in cancellous bone. Increasing the inclination in posterior implant resulting reduction of cantilever length and maximum stress reduction in bone. The effect of cantilever length is a dominant factor and can diminish stress even with lower number of implants. Angulations of the implant can reduce cantilever forces when the applied load is in the same direction of implant angulations.

REFERENCES


13. Marco Bevilacqua, DDS, Tiziano Tealdo, DDS, MS, DT, Maria Menini, DDS, Francesco Pera, DDS, Alexei Mossolov, ENG, Carl Drago, DDS, MS, and Paolo Pera, MD, DDS, PhD. The influence of cantilever length and implant inclination on stress distribution in maxillary implant supported fixed dentures


17. Anju Kumari, Puja Malhotra, Shefali Phogat, Bhupender Yadav, Jaiveer Yadav, Sumit Singh Phukela. A finite element analysis to study the stress distribution on distal implants in an all-on-four situation in atrophic maxilla as affected by the tilt of the implants and varying cantilever lengths. © 2020 The Journal of Indian Prosthodontic Society | Published by Wolters Kluwer – Medknow.