*International Journal of Health Sciences and Research*
*Vol.10; Issue: 2; February 2020*
*Website: www.ijhsr.org*
*ISSN: 2249-9571*

*Original Research Article*

# Finite Element Analysis of Crown to Implant Ratio on Stresses around Short Wide Implants - Part 1

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## ABSTRACT

**Purpose:** The purpose of the study is to evaluate the influence of crown to implant ratio on the stress around short wide implants and to compare short cylindrical implant to short conical implant using a finite element analysis method.

**Materials and method:** A total of four models was constructed with internal hex cylindrical implants and tapered conical short implants both measuring 5mm in diameter and 6 mm in length and corresponding crowns to simulate 1:1 and 2:1 crown implant ratios using HYPERMESH 10 software. CBCT images of the maxilla were converted to stereo lithography file. A vertical bite force of 150N that simulate masticatory force was applied axially and obliquely.

**Results:** On comparison, cylindrical implants showed better stress distribution throughout the implant but in conical implants it was concentrated at the crestal region. Irrespective of the geometry and/ or C/I ratio, both the implants showed significant increase in stresses at the bone and implant under oblique loading.

**Conclusion:** Maximum von Mises stresses were found in the crestal region of both the implants with 2:1 crown implant ratio. The stresses were concentrated more in the crestal region when compared to cortical bone and trabecular bone. In cylindrical implants, stresses were distributed along implant body when compared to tapered conical implants where stresses were concentrated at the crestal region. Greater stresses were generated by oblique forces when compared to axial forces.

***Key Words-*** Short dental implants, finite-element method, crown implant ratio, internal hex, tapered implants, and cylindrical implant.

## INTRODUCTION

Implants are used successfully as an alternate treatment option to restore the function of complete and partial edentulous patients. Goals for the success of implant dentistry include simplifying the procedures, reducing the duration of therapy for the patient and clinician, and use of conventional prosthodontic techniques.

The osseointegrated dental implant simulates the natural teeth as it is exposed to static and dynamic loadings continuously. However, the transmission of functional forces to jaw bone via implant supported prosthesis is probably quite different from that via natural teeth with a healthy periodontium.[1] The challenges in determining a dental implant system is to create a favorable biomechanical environment that prevents the surrounding bone from resorbing and failing under normal occlusal loads.

Anatomic conditions like reduced residual ridge height seen in areas such as posterior maxilla and mandible presents a challenge for rehabilitation. The available bone height in the posterior region of the arch is restricted by the presence of the inferior alveolar nerve and mental foramen in the mandible and maxillary sinus in maxilla.[2]

An alternative option to compensate for limited bone height in the posterior maxilla is sinus lift augmentation using autogenous bone or bone substitutes. Sinus bone grafting has been accepted as a treatment option in such situations, and may provide sufficient bone quality and quantity for implant placement and prosthetic support. However, the risk of morbidity, time and cost relative to other alternatives should be taken into consideration when sinus bone grafting is considered.[3]Yet another alternative treatment option is the use of short implants. Studies have shown the same level of clinical success for short implants when compared to a longer implant. [4]

Finite elements analysis methods are extremely versatile and powerful and can enables the designer in tackling many problems that are puzzling for conventional methods because of structural and material complexity.

The use of short implant is widespread in posterior maxillary and mandibular regions and several authors have demonstrated that it is possible to have higher C/I ratios without compromising the outcome of implant prosthetic rehabilitation.[5,6]

One of the major concerns with short implant is longer supra structure when compared to the implant length, which in other words means that restorations on short implants have a crown/implant ratio higher as it is placed posteriorly where the bone height is reduced.[7] However, studies have shown that crown implant ratio had neither the technical nor the biological effect on the clinical performance of the implants .[6]

Crown /root ratio has been one of the diagnostic parameters to decide on the restoration form of the dental prosthesis; however the ideal crown/implant ratio is not established yet.[8] A high crown/implant ratio will introduce significant moment on the implant and surrounding crestal bone when the implant restorations are subjected to lateral forces. The greater the moment of force, the greater stress on the alveolar ridge leading to crestal bone loss.[9]

Hence the aim of the study was to evaluate stresses around two short wide implants supporting single crowns with different crown to implant ratios.

## MATERIALS & METHODS

An edentulous maxillary specimen was collected from the Department Of Anatomy, The Oxford Dental College and Hospital; Bangalore. A Cone Beam Computed Tomography (CBCT) of the maxilla was taken at Magnus diagnostics Bangalore. These C.T images were converted to a CAD/CAM models. The properties of the short wide implants and the porcelain fused to cobalt chromium crown will be obtained from standard text book reference of implantology and dental material. The study was done using a three dimensional Finite Element Analysis technique on a workstation computer using ANSYS software for finite element analysis.

The study involved the construction of geometric models maxilla, implant and crown, followed by the application of different loads and boundary conditions. This was followed by the analysis of stress patterns.

## CONSTRUCTION OF GEOMETRIC MODEL

### MODELLING OFMAXILLA

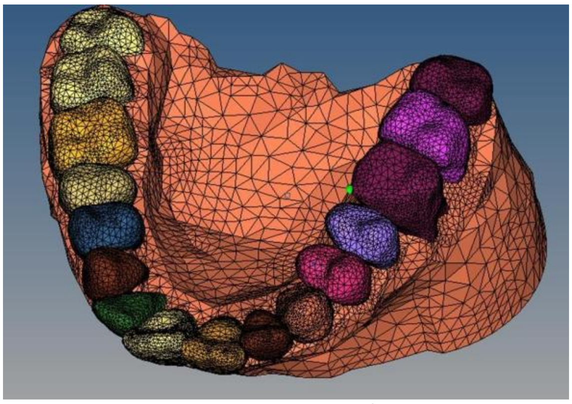

**FIGURE 1: FEM model of maxilla**

## MODELLING OF IMPLANT ANDCROWN

**Table 1: Four sets of models**

| SL NO | MODELS |
|---|---|
| 1. | Short cylindrical implant in maxillary first and second molar region with corresponding crown measuring 6mm |
| 2 | Short cylindrical implant in maxillary first and second molar region with corresponding crown measuring 12mm |
| 3 | Short tapered conical implant in maxillary first and second molar region with corresponding crown measuring 6mm |
| 4 | Short tapered conical implant in maxillary first and second molar region with corresponding crown measuring 12mm |

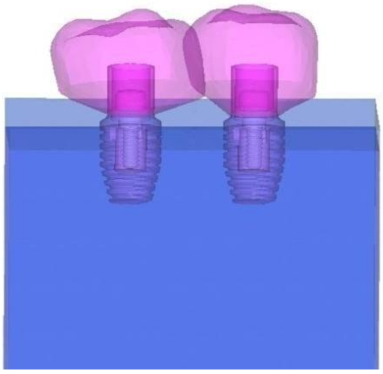

**FIGURE 2: MODEL 1 - Cylindrical implant assembled in maxilla with prosthesis of 1:1 C/I ratio**

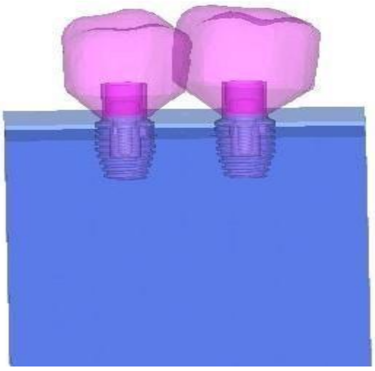

**FIGURE 3: MODEL 2 - Cylindrical implant assembled in maxilla with prosthesis of 2:1 C/I ratio**

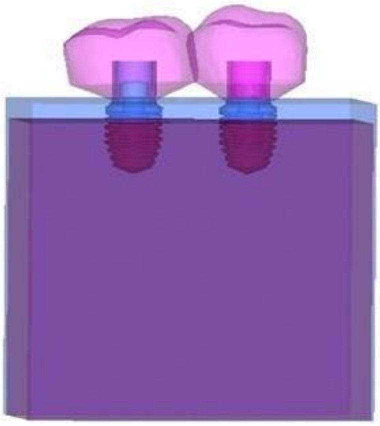

**FIGURE 4: MODEL 3 - Tapered conical implant assembled in maxilla with prosthesis of 1:1 C/I ratio**

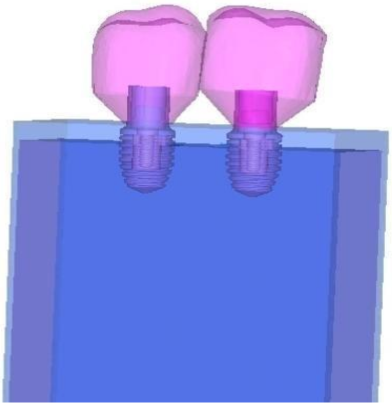

**FIGURE 5: MODEL 4 - Tapered conical implant assembled in maxilla with prosthesis of 2:1 C/I ratio**

## APPLICATION OF LOADS

A vertical bite force of 150N that simulate masticatory force was applied axially (90 degree to the long axis) and obliquely (30 degree to the long axis).

## ANALYSIS OF STRESS

The stress analysis implemented by ANSYS provided results that enabled the tracing of Von Mises stress field in the form of color-coded bands. Colour gradients ranging from red to blue with red representing the maximum stress values, which is given in Mega Pascal (Mpa). Analysis of stress was done under the following conditions:

1. Stress around bone supporting the internal hex cylindrical implants with crown implant ratio of 1:1 with bite force of 150N force applied axially (90 degree to the long axis) and obliquely(30 degree to the long axis)
2. Stress around bone supporting the internal hex cylindrical implants with crown implant ratio of 2:1 with bite force of 150N force applied axially(90 degree to the long axis) and obliquely (30 degree to the long axis)
3. Stress around bone supporting the internal hex tapered conical short

implants with crown implant ratio of 1:1 with bite force of 150N force applied axially (90 degree to the long axis) and obliquely(30 degree to the long axis)

4. Stress around bone supporting the internal hex tapered conical short implants with crown implant ratio of 2:1 with bite force of 150N force applied axially( 90 degree to the long axis) obliquely (30 degree to the long axis)

## RESULTS

Stress around bone supporting the internal hex cylindrical implants with crown implant ratio of1:1.

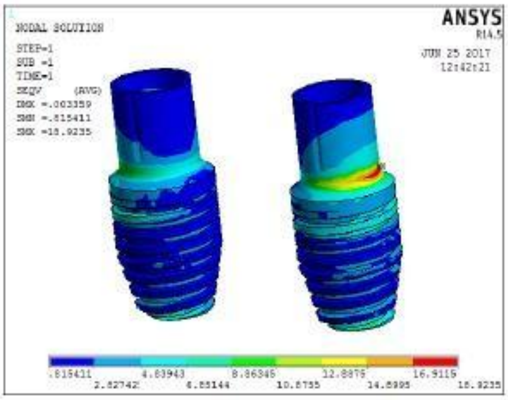

**FIGURE 6: Diagram representing stresses of 18.2 Mpain implant region, 7.33 Mpa stresses in the cortical bone, and 1.29Mpa stresses in the trabecular bone under an axial load**

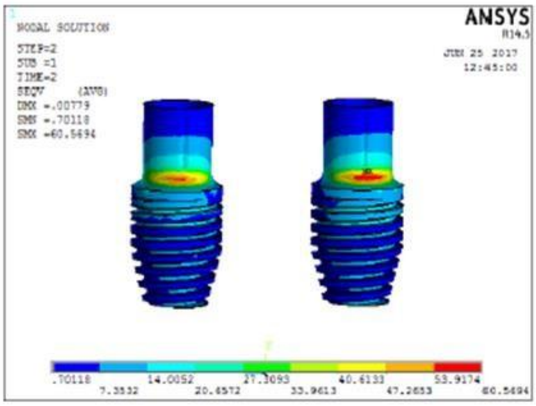

**FIGURE 7: Diagram representing stresses of 60.5Mpain implant region, 21.9Mpa stresses in the cortical bone, and 1.59Mpa stresses in the trabecular bone under oblique load.**

Stress around bone supporting the internal hexcylindrical implants with crown implant ratio of 2:1

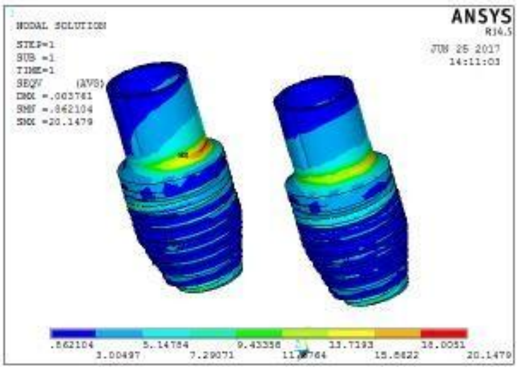

**FIGURE 8: Diagram representing stresses of 20.14Mpa in implant region, 6.43Mpa stresses in the cortical bone, and 1.27Mpa stresses in the trabecular bone under axial load.**

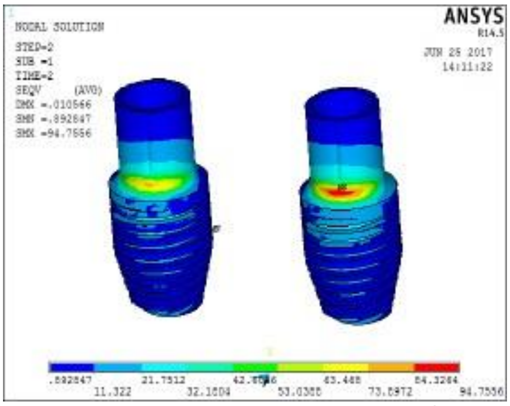

**FIGURE 9: Diagram representing stresses of 94.7Mpa in implant region, 30.6Mpa stresses in the cortical bone, and 1.98Mpa stresses in the trabecular bone under oblique load.**

Stress around bone supporting the internal hex tapered conical short implants with crown implant ratio of1:1.

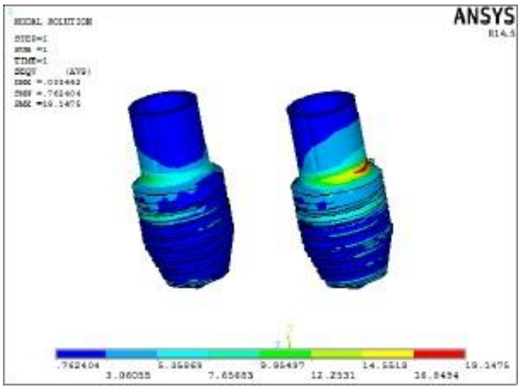

**FIGURE 10: Diagram representing stresses of 19.4Mpa in implant region, 7.52Mpa stresses in the cortical bone, and 1.16Mpa stresses in the trabecular bone under axial load.**

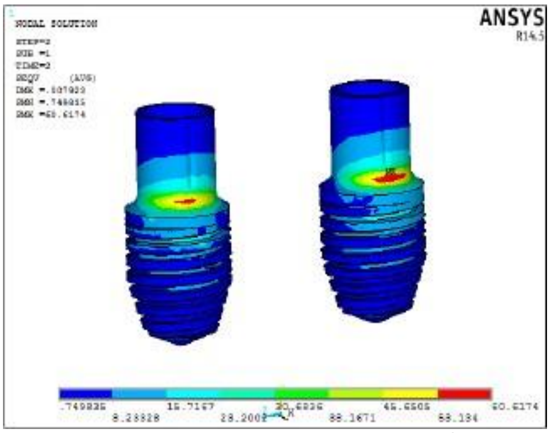

**FIGURE 11: Diagram representing stresses of 60.6Mpa in implant region, 22.2Mpa stresses in the cortical bone, and 2.20Mpa stresses in the trabecular bone under oblique load.**

Stress around bone supporting the internal hex tapered conical short implants with crown implant ratio of 2:1

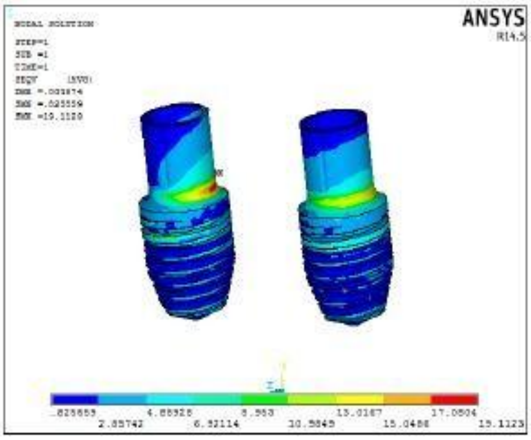

**FIGURE 12: Diagram representing stresses of 19.11Mpa in implant region, 6.62Mpa stresses in the cortical bone, and 1.27Mpa stresses in the trabecular bone under axial load.**

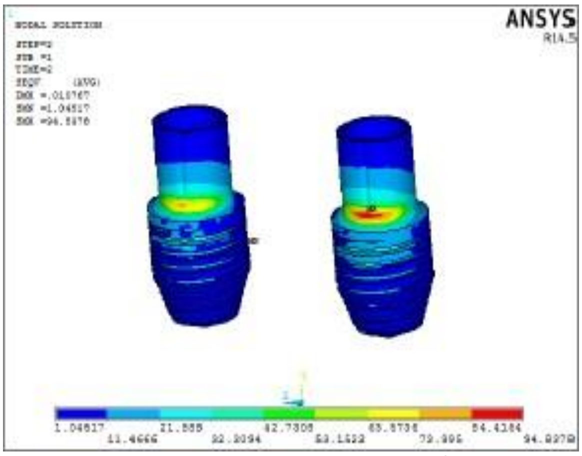

**FIGURE 13: Diagram representing stresses of 94.83Mpa in implant region, 31.3Mpa stresses in the cortical bone, and 2.80Mpa stresses in the trabecular bone under oblique load**

## DISCUSSION

Short implants appear to be a rational alternative to vertical bone grafting of resorbed alveolar ridges, especially in the posterior maxillae and mandible.[6] According to Das Neves et al, short implants are defined as implants measuring less than 10 mm in length. Other authors[2] consider short implants to be implants measuring 8 mm or less in length. Implants measuring 10 mm being regarded as conventional implants, due to their widespread use in recent years.[2]

It is necessary to understand the stress distribution patterns around short-wide implants and how they are affected by different types of implant geometry, fixture connection, or C/I ratio. Crown implant ratio has been reported as a potential risk for prosthetic and biological complications.

Stress analysis of dental implant is necessary for the investigation of bone turnover and maximum anchorage success. Incorrect loading or overloading may lead to consequent implant loss.

When cylindrical and tapered conical implants with 1:1 and 2:1 crown implant ratio were subjected to forces, the stress distribution in cylindrical implant was seen throughout the implant body. Whereas in conical implants stresses were concentrated around the crestal region only. As Mish stated, lesser the surface area of a tapered implant greater the stresses at the crestalregion.[10]

Tapered configuration of the conical short implant contributes to the concentration of stresses around the crestal region which has a deleterious effect on the underlying bone and implant.

With limited availability of bone in the posterior region, the short implants are preferred over the invasive surgical procedures. But when short implants are used to rehabilitate the posterior region it generally leads to poorer or 2:1 crown implant ratio. When the implant restoration is subjected to both axial and oblique forces, this increase in the crown to implant ratio tends to have greater moment of force, thereby greater stresses which eventually leads to crestal bone loss.

Short conical implants with 2:1 crown implant ratio showed increase in stress especially around the crestal region of bone and implant.

The biomechanical performance of short implants depends on many important factors to predict long term success. In clinical situations the masticatory forces are not purely axial or oblique directions. Crown implant ratio and implant geometry has a great effect in load transmission as well as stress distribution. Hence further studies are necessary to evaluate short wide implants to increase their longevity.

## CONCLUSION

Within the limitations of the study, following conclusions were drawn:

1. Maximum von Mises stresses were found in the crestal region of the bone and implants of both cylindrical short implant and tapered conical implant with crown implant ratio of2:1.
2. Stress distribution in both types of implants were found concentrated more in the crestal region of implants followed by cortical bone and lastly in trabecular bone.
3. In Internal hex cylindrical implants, stresses were distributed throughout the implant body when compared to tapered conical implants where in stresses were concentrated at the crestal region.
4. Greater stresses were generated by oblique forces when compared to axial forces.

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How to cite this article: Dayalan M, Kumar RS, Altaf MS et.al. Finite element analysis of crown to implant ratio on stresses around short wide implants – part 1. Int J Health Sci Res. 2020; 10(2):253-258.

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