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Implant Body Von Mises Stress: Does it follow a Pattern of Reduction Along its Length from Cervical to Apical Third?

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1. Abstract

Dental Implantology is one of the technically advanced fields in Oral and Maxillofacial Surgery with a multi-disciplinary collaboration especially with that of biomechanical engineering. The Von mises stress in and around the dental implants have been analysed by bio-engineers for more than a decade. The clinical effects of increased or decreased stress beyond the physiological yield values have also been analysed. The Von mises stress have been well documented to get concentrated in the cervical area of the implant and that the stress progressively decreases towards the apex.

However, the progressive stress reduction pattern from cervical to the apical area of the implant has not been well documented. The current article is a study using a patient specific clinical FEA study where the authors have noticed a pattern in the implant internal body von mises stress reduction along the length from the cervical to the apical 3rd irrespective of the implant diameter and length. The biomechanical and clinical significance of this factor needs to be investigated. This would need further exploration which could bear implications in biomechanical engineering and implant design modifications in future.

2. Introduction

Dental implants are the most common means of functional and aesthetic rehabilitation edentulous space. The choice of the diameter and the length of implants during rehabilitation is dependent on various factors. Long term success of such implants is dependent on the effect of Von mises stress in the implant body and also on the peri-implant bone. Much of the studies in the literature have focussed on the cervical bone resorption secondary to Von mises stresses at the cervical interfacial peri-implant bone stress [1]. Internal implant body stress is also critical for the success of implant. It is well known that implant body Von mises stresses on loading are concentrated around the cervical 1/3rd of the dental implants [2]. Though the stress concentration decreases progressively towards the apex, the pattern of stress reduction towards the apex has not been documented in the scientific literature to the best of our knowledge. The current article is a report of a patient specific clinical FEA study where the authors have noticed a pattern in the implant internal body von mises stress reduction along the length from the cervical to the apical 3rd irrespective of the implant diameter and length.

3. Material and Method

The study used patient specific FEA models of osseointergrated endosseous dental implant of varying dimensions commonly used in clinical practice (10mm x 4.5mm, 12mm x 4 mm and 3.3mm x 14 mm) generated using lead foil crown delineation technique as described by S Sundar and S K Shetty. The finite elements on X axis were assumed to be fixed and tetrahedral in shape. The bond between implant and bone was fixed. A vertical load of 40 Ncm and 200 Ncm simulating normal and heavy bite force were simulated as point load on the nodes in the central fossa/incisal edge to represent force on light biting and hard biting respectively. The models were analysed using ANSYS

18.1 software. The overall Von mises stress in the implant body was recorded in the cervical and apical $1/3^{rd}$ and tabulated as given in Table 1 and Figure 1.

Table 1: Overall cervical 1/3rd and apical 1/3rd Von mises stress distribution pattern

Implant dimension	Von Mises stress at the cervical $1/3^{rd}$ of implant in MPa		Von Mises stress at the apical $1/3^{rd}$ of implant in MPa	
	40Ncm	200Ncm	40Ncm	200Ncm
10mm (L) x 4.5 mm (D)	52.8	415.92	3.17	24.71
12mm (L) x 4mm (D)	348.71	719.05	20.68	42.65

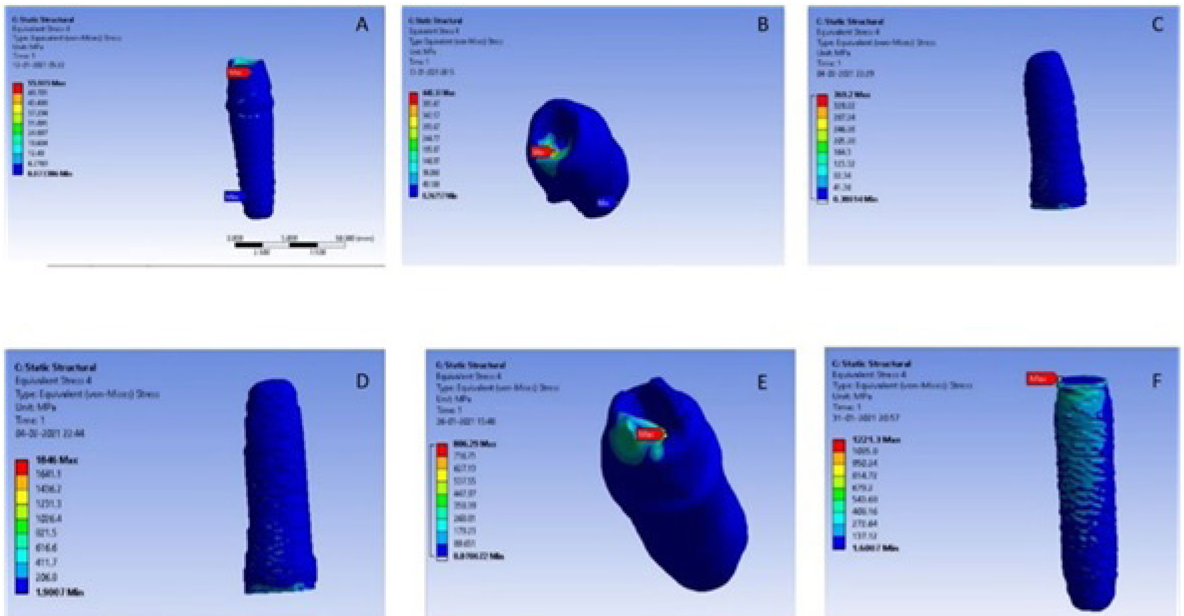

Figure 1: Von mises stress in the implant body at varying dimensions and loads - A,B: 4.5mm (D)X10mm(L) implant at 40N(A)&200N(B); C,D: 4mm(D) x 12mm(L) implant at 40 N(C) & 200N(D); E,F: 3.3mm(D)x14mm (L) implant at 40N(E) &200N (F)

4. Results

The overall cervical $1/3^{rd}$ stress in a 4.5mm diameter 10mm long implant was measured to be 52.80 Mpa at 40 N load and 415.92 Mpa on 200N load. The Apical $1/3^{rd}$ stress on 40N load was 3.17Mpa and at 200N load was 24.71 Mpa. The ratio of cervical $1/3^{rd}$ to apical $1/3^{rd}$ stress at 40 N was observed to be 16.65 and at 200 N observed to be 16.83.

The overall cervical $1/3^{rd}$ stress in a 4mm diameter 12mm long implant was measured to be 348.71 Mpa at 40 N and 719.05 Nat 200N of static axial load. The Apical $1/3^{rd}$ stress on 40N load was 20.68 and at 200N load was 42.65 Mpa. The ratio of cervical$1/3^{rd}$ to apical $1/3^{rd}$ stress at 40N was observed to be 16.86 and at 200N was 16.86

The overall cervical $1/3^{rd}$ stress in a 3.3mm diameter 14mm long implant was measured to be 496.10 Mpa at 40 N and 1217.05MPa at 200N of static axial load. The Apical $1/3^{rd}$ stress on 40N load was 29.36 MPa and at 200N load was 73.23 Mpa. The ratio of cervical1/3rd to apical $1/3^{rd}$ stress at 40N was observed to be 16.89 and at 200N was 16.61.

A 4.5 mm diameter and a 10mm length implant recorded the least internal implant body stress. A 3.3mm diameter and a 14mm long implant recorded the highest internal implant body stress. The overall Von mises stresses at the apical $1/3^{rd}$ of implant was approximately 17 times less than the stress at the cervical $1/3^{rd}$ of the implant irrespective of the implant dimension (length and diameter).

5. Discussion

Clinical/Biomechanical Importance and Scope for Further Innovations

The Von mises stress in and around the dental implants have been analysed for more than a decade. The clinical effects of increased or decreased stress beyond the physiological yield values have also been analysed [3]. The implant body internal stress has been documented to be more than the peri- implant bone stress due to the difference in the elastic modulus between the implant metal and the bone [4]. The Von mises stress get concentrated in the cervical area of the implant and the stress progressively decreases towards the apex. However, the progressive stress reduction pattern from cervical to the apical area of the implant has not been well documented. In this study, the authors have noticed a pattern of stress reduction which was a constant ratio approximating 'factor 17'across varying implant diameter and length. The biomechanical and clinical significance of this factor needs to be investigated. This would need further exploration which could bear implications in biomechanical engineering and implant design modifications in future.

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