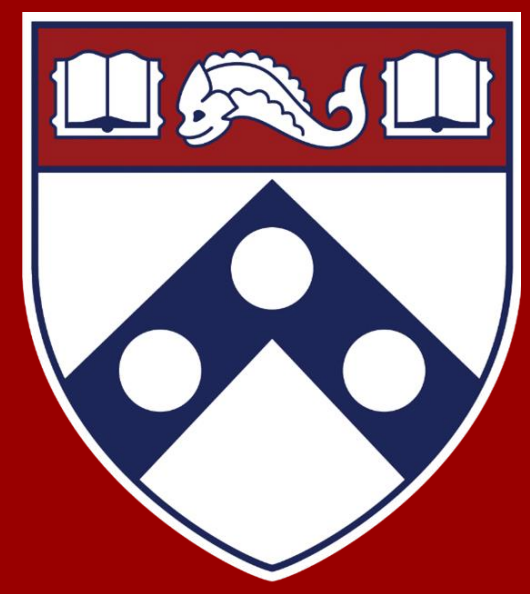




Evaluation of Changes in Stress Distribution Around an Implant with and without the Presence of Bone Grafting

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AIM OF STUDY

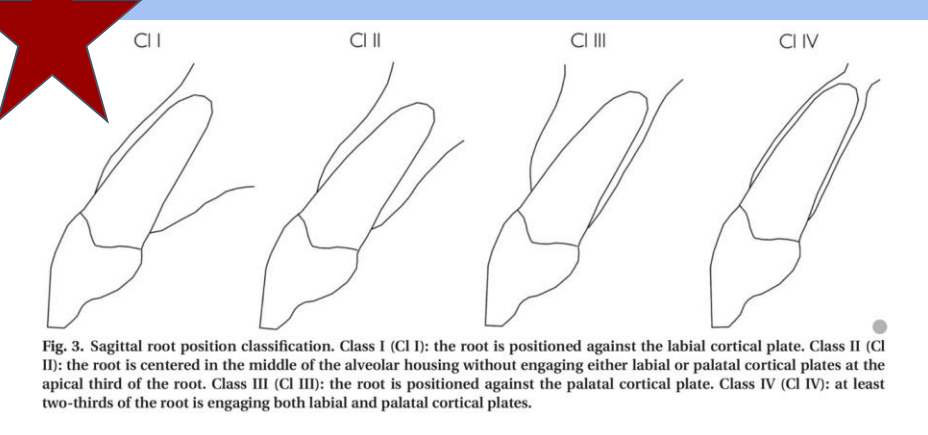
To evaluate the stress distribution pattern in bone surrounding an immediately loaded maxillary anterior implant which requires bone graft. The study aims to compare the biomechanical difference in surrounding bone due to the presence and absence of graft material, bio-oss collagen, as compared to an immediately loaded implant placed in adequate bone. Finite Element Analysis was used to assess the biomechanical changes.

INTRODUCTION

- Immediate implant placement is a favorable procedure in anterior zone due to its ability to preserve soft tissue and hard tissue structure.
- Grafting assures adequate positioning of labial cortical plate and helps maintain osseous - gingival tissue relationship (Araujo 2009)
- Graft aids in increased bone mineral density of newly formed bone can counteract the marginal ridge contraction.(Araujo and Lindhe 2009)
- Bone grafting helps overcome limitations arising due to lack of bone grafting
- 93% cumulative survival and 88.1% cumulative success rate for immediate implants with bone grafts.

ITI CONSENSUS - CASE SELECTION - IMMEDIATE LOADING

- Intact socket walls
- Labial bone <1mm
- Thick biotype
- Absence of acute infection
- Primary stability



ITI CONSENSUS - TIMING OF LOADING

- 20-45N torque at the time of placement
- no systemic condition
- more benefit than risk

- Previously, studies have studied graft material via histological (Araujo) and cone beam computed tomography Methods (Degidi).
- Degidi reported that grafting can reduce labial crest reduction from 1 +/- 2mm to 0.76 +/- 0.96mm.
- Sanz et al in 2010 reported a 36% coronal horizontal reduction. However the placement of graft prevents the loss of labial plate. (Araujo 2011)
- Botticelli 2004 demonstrated that the horizontal gap between implant and labial bone cannot always be completely filled.
- Paolantonio et al. 2001 reported that immediate implant placement avoids resorption process of labial bone plate.
- However, Araujo in 2005 reported that immediate implant placement significantly affected labial plate resorption.
- There has been conflicting evidence about the efficacy of graft material to maintain ridge morphology. But it is evident that bone graft alters post extraction socket healing in association with implant placement.
- The study aims to study the distribution of biomechanical forces around the grafted extraction socket and implant.

METHOD

Study model was constructed based on parameters required to achieve primary stability and ITI case selection criteria for immediate loading with a gap between labial cortical plate and implant measuring between 1 - 4 mm.

A 3-dimensional FEA model of an anatomical maxilla bone block with crestal cortical bone and cancellous bone from tooth #6 - #11, and standard thread Ø4.0 × 13 mm implant were developed. Right maxillary central incisor was digitally extracted to simulate socket space.

The control model (T_C) consisted of a implant at a fully healed extraction site. The extraction socket was considered as healed and filled with remodeled cancellous bone. Palatal aspect and 3mm of apical implant was engaged with cancellous bone to ensure primary stability. The bone-implant interface was set as a contact (between 40-50%) as no osseointegration was considered.

The study model (T₀) consisted of a implant with a grafting material in the extraction socket with same bone implant specifications as implant site. The interface between a bone graft-cancellous bone, implant-cancellous bone, and implant-graft were set as contact for the immediate loading because there was no ossification in the graft. A study model was also generated to simulate ossification of graft after a time interval(T_X) when the graft is partially ossified. Based on previous studies, we aim to assess the force distribution when the graft material achieves half the mechanical strength (elastic modulus, yield strength and tensile strength) of fully remodelled bone of created model. The material properties for components in the FEA model was determined using published data and research article while the ones for the graft (modulus, poisson's ratio, and etc) decided considering its morselized state (Table 1).

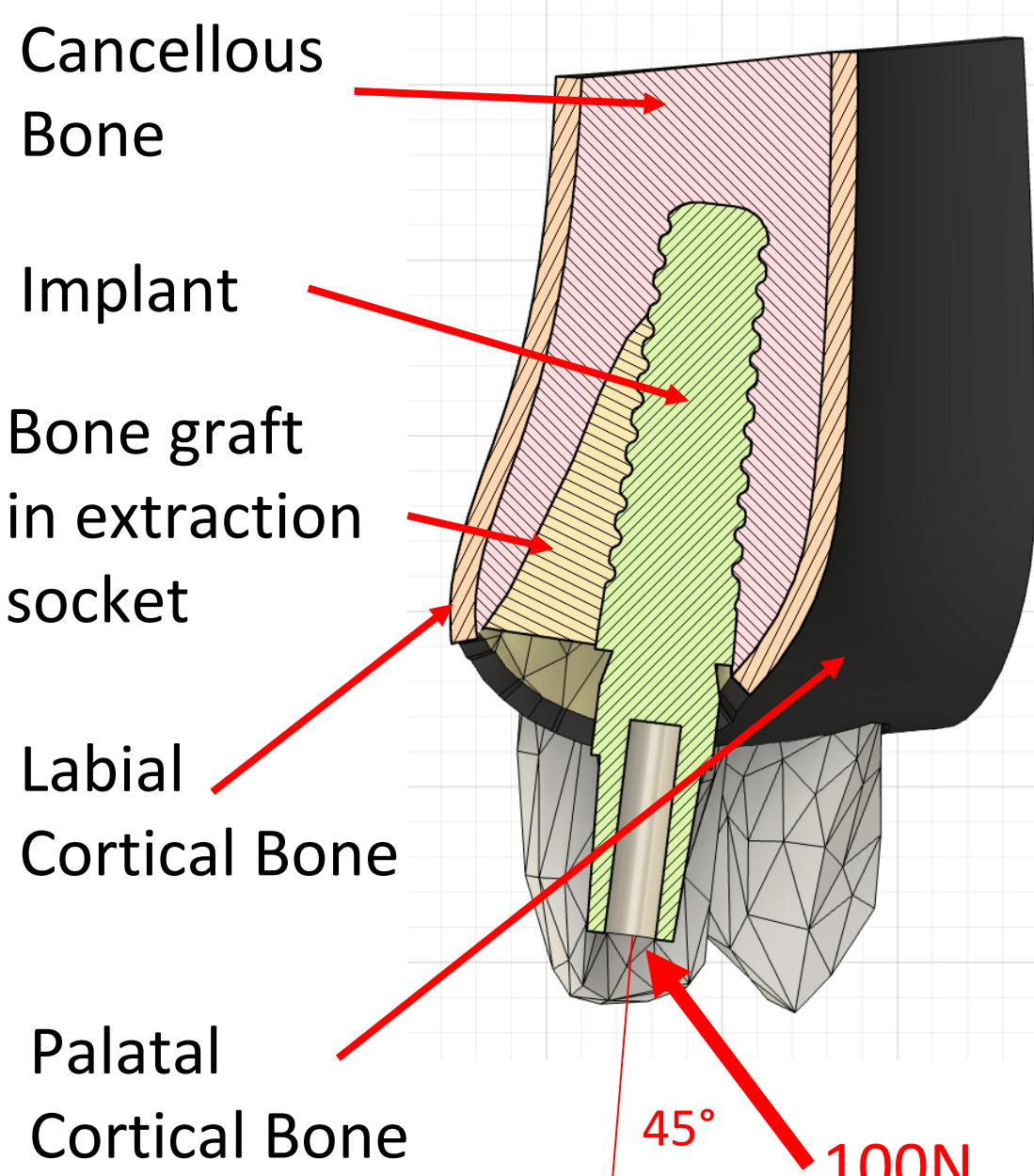


Fig1: Sagittal cross section view of FEA model (Left), Material properties for the model (Table 1)
A 100N force in labial gingival direction was applied on the abutment of the implant, and Von-Mises stress in an labial bone (cortical shell, cancellous bone, and around the apex of the implant) and a micromotion of the implant were analyzed.

	Ti-6Al-4V	Cortical Bone	Cancellous Bone	Bone Graft T ₀	Bone Graft T _X
Elastic Modulus (MPa)	105000	17000	2000	100-1600	1000
Poisson Ratio	0.32	0.30	0.30	0.2 - 0.3	0.25
Yield Strength (MPa)	830	49	4.8	0.05 - 1.45	2.4
Tensile Strength (MPa)	1050	52	N/A	N/A	N/A

Table 1. List of materials used in the FEA and their properties used for the simulation

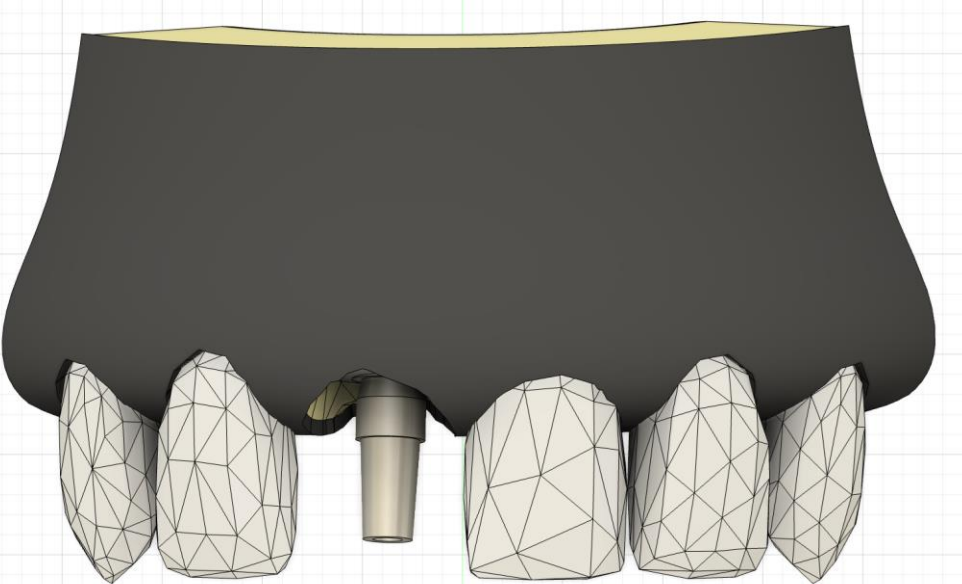


Fig 2: Frontal model view with the implant location

RESULTS AND DISCUSSION

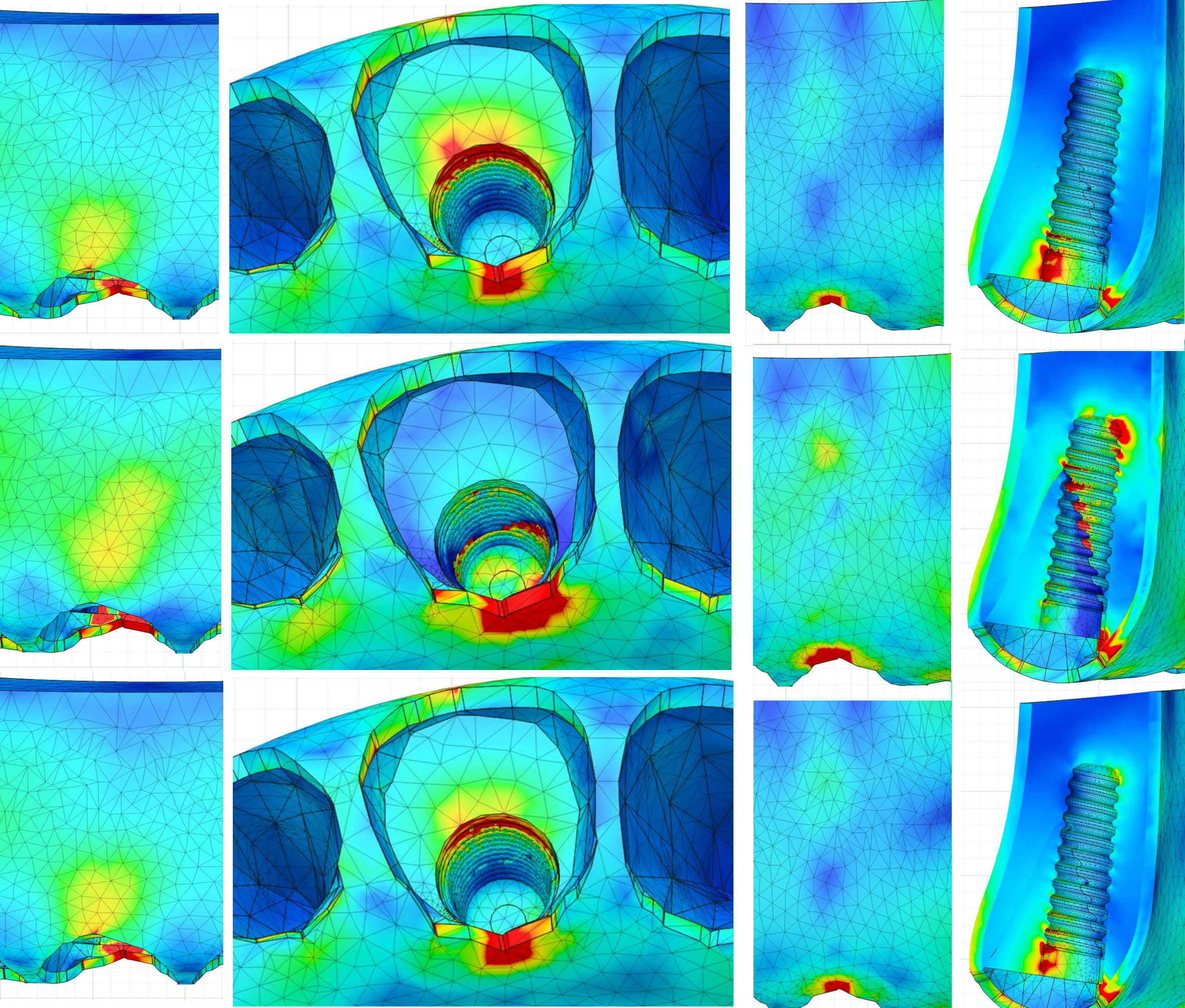


Fig 3 : Von-Mises stress [MPa] distribution of T_C, T₀, T_X (Top to Bottom)
From left to right, Labial view, Transverse view, Palatal view, and Sagittal view

	Labial Cortical	Palatal Cortical	Bone around the neck of implant	Bone around the apex of implant	Max displacement of implant
Control Model T _C	13.55	5.20	21.90	12.83	0.12
Study Model T ₀	11.40	11.50	7.20	46.60	0.30
Study Model after partial ossification T _X	15.30	6.10	16.50	15.61	0.41

Table 2. Stress in the labial bones and displacement of the implant from the FEA models

The results showed that the study model T₀ has much higher stress in palatal cortical bone right behind the apex of the implant than the control model. The stress pattern starts resembling control as the graft ossifies at T_X. In addition T_C and T_X showed even stress distribution in the labial bone around the implant as it was fully remodeled bone and higher stress in labial cortical plate.

For both palatal and labial cortical bone and cancellous bone, the study model showed much higher stress in the bone around the apex of the implant and interface between the graft and cancellous bone as no labial bone supports, while the control model and partially ossified model showed more evenly distributed stress in the bone. T₀ showed a stress distribution pattern unlike the one around T_C and T_X implant neck. Total displacement (combined in x, y, z directions) of the implant also showed the study model has higher displacement than the control model.

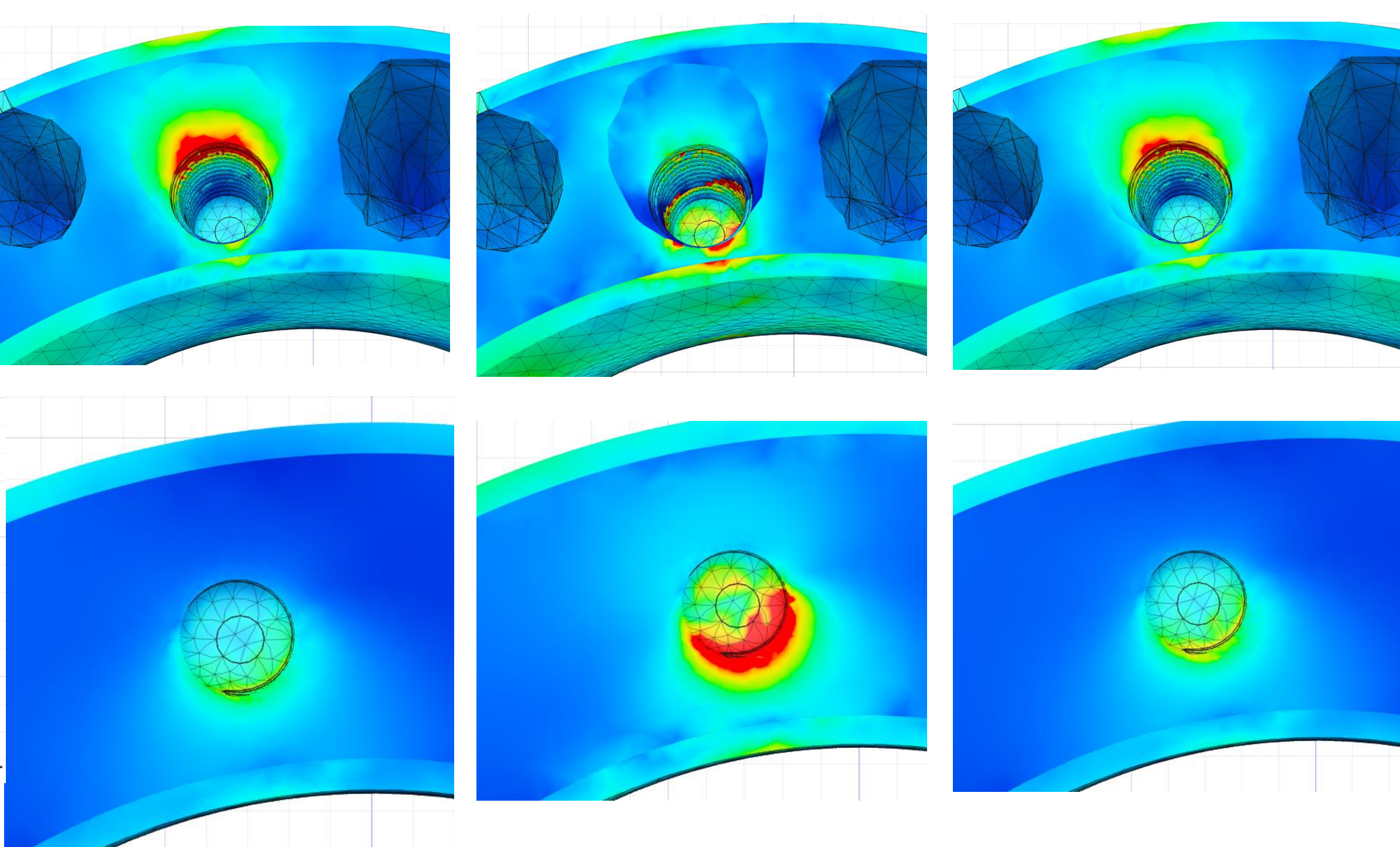


Fig 4: Transverse section view of labial bone at implant neck (Top) and apex (Bottom) T_C, T₀, T_X (Left to Right)

Dental implants have been introduced and advocated for the esthetic zone. This study aims to apply FEA models to represent the immediate loading and placement for a single unit implant in esthetic zone with grafting and compare it to an implant in fully healed bone. It was hypothesized that the stress/strain distribution might have been different.

The results demonstrated that higher Von-Mises stress and higher equivalent strain in labial bone, and larger displacement of implant in the study models with results simulating control as ossification continues.

Table 2 showed the study model has much higher stress [MPa] at palatal cortical bone (11.50 vs. 5.20) and labial bone around the apex of implant (46.60 vs. 12.83) while control model showed around 2-3 times higher stress at the labial bone around the neck of implant. Also higher than 15 MPa stress was observed at the interface between grafting and cancellous bone in the study model.

The max stress in these regions was much higher than the given yield strength of the cancellous bone (4.8 MPa) in this FEA, and may suggest peri-implant bone loss especially in the where bone resorption occurs more readily.

This study concludes similar to previous studies that graft material does not cause any significant difference in stress pattern as ossification continues, thereby asserting the use of graft material for improved hard and soft tissue contours.

Irrespective of graft material, there are aberrant forces present around a post extraction immediate loaded implant site that require diligent management of occlusal forces.

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CRITICAL ANALYSIS AND FURTHER EVALUATION:

1. These results may explain the risk of failure of osseointegration in immediate implant placement and loading compared to delayed loading
2. More studies are needed to make firm recommendations on early loading protocols
3. This study has similar limitations as previous studies, include the limited study designs, material properties of grafting material, occlusal loads, and individual variations.
4. The future study will include rate of ossification of the grafting material per different time points, implant location per grafting material, different graft materials

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