https://doi.org/10.33472/AFJBS.6.11.2024.1602-1611

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

FINITE ELEMENT ANALYSIS OF NOVEL ENDO IMPLANTS IN VARIOUS CLINICAL SCENARIOS INVOLVING ANTERIOR TEETH

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Article Info

Volume 6, Issue 11, July 2024

Received: 21 May 2024

Accepted: 27 June 2024

Published: 12 July 2024

doi: 10.33472/AFJBS.6.11.2024.1602-1611

ABSTRACT:

Background and Objective: Endodontic implants, or didontic implants, offer a promising solution for stabilising periodontally compromised teeth and prolonging their survival. Despite their potential benefits, existing endodontic implants face challenges such as material limitations and occasional failures. Novel designs and materials present an opportunity to overcome these challenges and enhance the clinical efficacy of endodontic implants.
Materials and Methodology: This study employs Finite Element Analysis (FEA) to assess the stress distribution of novel endodontic implants in maxillary anterior teeth. The design and material properties of the implants are carefully selected to enhance mechanical performance. The novel design of endodontic implant was placed under various loading conditions, involving two different clinical presentations of central incisor as compared to an intact tooth for comparison of stress distribution.
Results: The FEA analysis revealed favourable stress distribution that was comparable to that seen in an intact tooth. These studies can be used to fabricate future systems of endodontic implants that are biocompatible.
Conclusion: By leveraging advanced design principles and materials, these implants offer a promising alternative to traditional approaches, such as tooth extraction. Further clinical studies are warranted to validate the efficacy and long-term success of these novel endodontic implants in diverse patient populations.

Keywords: endodontic implants, titanium, anterior fractures

1. INTRODUCTION

Restoration and preservation of teeth especially in the anterior region, regardless of the periodontal status is critical. Often in some scenarios, such teeth deemed to have poor prognosis are referred for extraction followed by prosthetic rehabilitation. The primary reason is due to the lack of an alternative option.
Didontic implants implies ‘through the tooth’ in Greek. They are extensions composed of metals that may extend past the tooth's apex and into the underlying healthy bone, also known as endodontic endosseous implants (Ingle, Bakland and Craig Baumgartner, 2008). A time tested method for stabilising periodontally weak teeth has been provided by the endosseous implants' capacity to lengthen roots, change the ratio of root to crown measurement, support roots for overdentures, immobilise shattered or resorbed roots, and stabilise periodontally impaired teeth [2].

Though first advocated by Orlay amongst others, Frank was credited for setting a protocol in place, with standardised recommendations for the choice of endodontic implant size depending on the clinical situation (Frank, 1967). These were composed of sapphire, chrome-cobalt and vitalium initially and were first described in 1960 (Larsen, Patten and Wayman, 1989). Wein et al was the first to introduce designs like threaded and non-threaded. It had been suggested that the extension had to be 5mm past the apex, when in 1963 Strock technique was developed that involved making these posts with Titallium or Vitallium.

They are pivotal in retaining teeth with hopeless prognosis that could occur due to trauma or unfavourable periodontal conditions. Teeth with endodontic implants are known to have prolonged rates of survival. After a 5-year follow-up, the prognosis for endodontic implants was reported to be as high as 91% (Weine, 2004)

Finite element analysis (FEA) is a widely used method for studying dental biomechanics by dividing the geometry into small elements with known mechanical properties. Based on the concept of "moving from part to whole," this approach breaks the topic under investigation into digestible sections. The three main steps of the finite element analysis are preprocessing, which prepares the modelling data, processing of the assembly that solves the equations, and postprocessing, which visualises the findings after analysis (Piattelli, 2016). The rheological and physical characteristics of biological tissues and biomaterials are used to construct a model. To be more precise, figures pertaining to modulus of elasticity, stress, and Poisson's ratio of the material are required for the final construction. Wein and Frank conducted a 10 year follow up of their cases, and while there were several failures, there were also few great successes. Due to the inevitable loss of such teeth, any amount of extended stabilisation delaying the inevitable, can be considered a success for the patient. The failures are a consequence of a variety of factors such as insufficient implant preparation, inappropriate material utilisation, and poor case selection. Moreover, the rise and strides in osseointegrated implants in dentistry discouraged the use of endo stabilisers.

With the developments in dental materials, and success seen with titanium and bioceramics as biocompatible, there is now a wide range of surface possibilities for the Endodontic implants that may enhance their application and long-term clinical success. Their biocompatibility combined with the ability to preserve periodontal membrane attachment makes them a good alternative for preserving natural dentition (Romanos, 2005).
Hence, the aim of this study was to evaluate the stress distribution of novel Endo Implants inspired by the current popular titanium implants systems in various clinical scenarios of maxillary anterior teeth using Finite Element Analysis technique.

2. MATERIALS AND METHODS

This pre clinical software based study was conducted in Saveetha Dental College, Chennai. The aim is to design endo implants keeping the current successful systems of osseointegrated implants in mind. It was proposed that the after the healing phase of an endo implant, there is development of a periodontal ligament like structure around it at the level of the apex of the tooth (Parmar and Pramodkumar, 2000). The hardened membrane like structure is a mode of tissue integration which becomes a channel of stress distribution of the functional loads to the surrounding bone and is composed of osteostimulatory collagen fibres. This is called “Osteo Preservation” (Frank and Abrams, 1969).
Keeping this in mind as the end goal for a functional healing, the design of the endo implant models required the following -

1) Threads that would stabilise the endo implant, but not concentrate stress and cause crazing in the dentin
2) A Sluiceway for the cement to flow and express out coronally
3) Matched major diameter at the level of the apex in order to prevent root fracture
4) Smooth surface beyond the apex in order to connect with the osteostimulatory collagen fibres for osteopreservation
5) Head of the implant to match the coronal prepared space and taper with the canal

Novel design of the endodontic implant :
The pictographic design had been designed first with the dimensions as represented in Table 1. The thread was designed as a reverse buttress thread and the head was made circular in order to screw it into the tooth structure. Except for the apical 4mm, the endo implant had threads throughout. The reverse buttress thread would not engage the dentin walls to a great extent and hence in order to increase surface area of adaptation the design was finalised. The finished digital model for the same is represented in Figure 1.

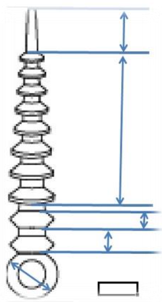
DIMENSIONS	**MODEL 3**
Pictorial representation	
Length of the head	**0.5**
Length of the shaft	**0.5**
Length of screws	**12**
Length of the apical extension	**4**

Table 1 : Representation of the design and of dimensions for the novel endodontic implant

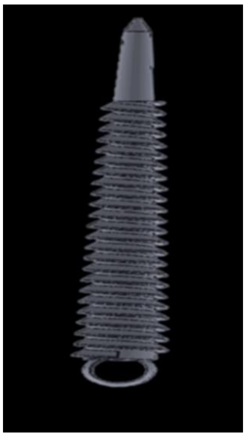


Figure 1 : Representation of the final three dimensional model of the endodontic implant to be evaluated in anterior teeth

After the designing and exporting of the models, a computer-simulated tooth model was composed of separate components connected at nodes, which were formed from the material properties. Meshing was done after the model had been constructed and boundary conditions were established to ensure that the body under assessment was confined when stress was applied (Korkmaz and Kul, 2022). The alveolar bone along with the maxillary central incisor were the first parts of the model to be created. This is represented in Figure 2.

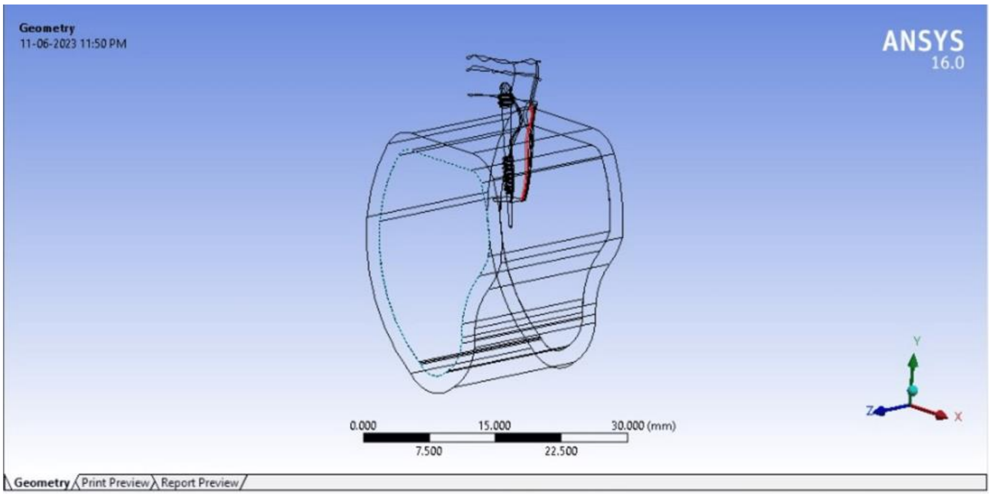


Figure 2 : Figure representing a schematic model (ANSYS software) of maxillary central incisor, alveolar bone, and endodontic implant placed within the apical extension. The head is placed at the level of the cingulum palatally

These models represent circumstances similar to the oral cavity, and are simulated, and built using evidence-based scientific data to estimate the mechanical properties of materials, such as Poisson ratio and Young's modulus. It was assumed that all materials were linearly elastic, homogenous, and isotropic. The models were meshed, boundary conditions were created, and the load was measured on the palatal region 2 mm below the incisal edge, At 45° angle, a constant axial load value of 600N is applied after the application of a boundary condition. The next step was to do three-dimensional FEA using ANSY software.

Workflow involved:

- Preparation of Maxillary bone model
- Maxillary Central incisor model
- Assembly
- Creation of periodontal ligament
- Separation of Cortical and cancellous bone
- Creation of enamel, dentine, pulp and pulpal space
- Creation of endodontic implant models
- Creation of endodontic implant beyond root apex
- Application of Material properties
- Meshing
- Analysis for the given loads in intact and clinical scenarios were assessed.
- Capturing the required results.

The statistical analysis was conducted with parametric tests and the results were verified using SPSS 2.0 software**.**

For the evaluation of stress distribution, two clinical conditions were taken into consideration. Firstly, one that is commonly seen wherein tooth has undergone root resection or root

resorption presenting with poor crown:root ratio. This is represented by a three dimensional model in Figure 3 depicting Model 1.
The second clinical scenario is one wherein the tooth has poor periodontal prognosis as a factor of mobility or loss of clinical attachment. This is represented in Figure 4 depicting Model 2.

Figure 3 : Picture representing the different clinical scenarios – wherein tooth has root resection/root resorption presenting with poor C:R ratio. This has been depicted as Model 1.

Figure 4 : Picture representing the different clinical scenarios – wherein tooth has poor periodontal prognosis due to mobility and loss of clinical attachment. This has been depicted as Model 2.

3. RESULTS

The FEA was done for all three models, which showed that the maximal stress concentration is on the incisal edge. This is a good indication, as the weakest point is not situated at the junction between the endodontic implant and the coronal/apical region of the tooth, potentially preventing catastrophic failures during clinical situations.

Figure 4 represents the results of FEA analysis for Model 1, clinical condition involving poor C:R ratio.

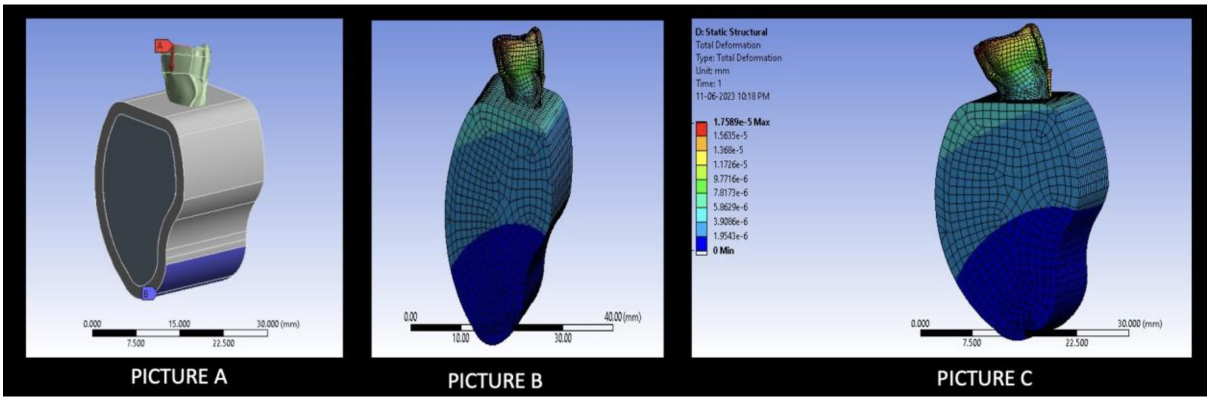


Figure 5: The picture depicts the novel 3D model of Model 1 (ANSYS software). Picture A depicts the stress applied on the incisal edge to study stress generation (70N). Picture B depicts the total stress generated on the tooth structure after the placement of the endodontic implant in Model 1. Picture C depicts the stress generated on an intact model

Figure 5 represents the results of FEA analysis for Model 2, clinical condition involving poor periodontal prognosis.

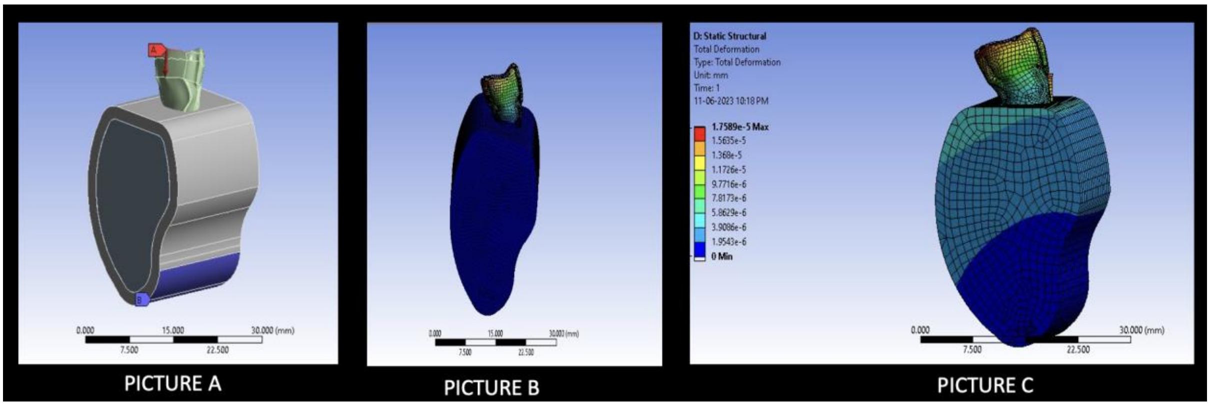


Figure 6: The picture depicts the novel 3D model of Model 2 (ANSYS software). Picture A depicts the stress applied on the incisal edge to study stress generation (70N). Picture B depicts the total stress generated on the tooth structure after the placement of the endodontic implant in Model 2. Picture C depicts the stress generated on an intact model

The *Figure 6 depicts the novel 3D model of Model 2 (ANSYS software). Picture A depicts the stress applied on the incisal edge to study stress generation (70N). Picture B depicts the total stress generated on the tooth structure after the placement of the endodontic implant in Model 2. Picture C depicts the stress generated on an intact model*

Table 2 represents the maximum stress of deformation subjected on both the models in comparison to that seen in an intact tooth.

MODEL	MAX. STRESS OF DEFORMATION
INTACT	1.7589e-5 MAX
MODEL 1	2.638e-5 MAX
MODEL 2	2.1986e-5 MAX

Table 2 : The stress level of deformation obtained through ANSYS software on applying the functional loads for the two models

4. DISCUSSION

Preserving and extending the longevity of the natural dentition is the priority whenever possible even in clinical cases that produce guarded prognosis. According to Frank and Abrams, an appropriately positioned endodontic implant is accepted by the periapical tissue, where the titanium metal implant is encircled by a thin, healthy fibrous connective tissue "collar" that resembles a periodontal ligament-like tissue of natural teeth. This hardened membrane-like structure is a mode of tissue integration that becomes a channel of stress distribution of the functional loads to the surrounding bone and is composed of osteostimulatory collagen fibers. This is called “Osteopreservation” [11].

When it was introduced, the endodontic implants were made of materials that were not completely biocompatible with the periapical tissues. They caused tissue reactions that were not conducive to osteopreservation. This was one of the critical reasons for the failure of endodontic implants in clinical situations [12]. The introduction of titanium along with variations like titanium alloys with vandium and aluminium has opened the door for various grades of materials that are bio-inert and biocompatible. Hence, this study was conducted to design novel designs of endodontic implants in order to re-introduce them in contemporary clinical dentistry using titanium as the material of choice. The proposed causes of failure of these previous implant designs were attributed mainly to lack of achievement of the apical seal, screwing-in of the implant within the tooth, along with crazing and crack propagation in the dentine, and finally poor retention in the bone beyond the root apex [13,14].

As seen with the results in the FEA, the stress patterns found in the tooth models were favorable and comparable to those seen in an intact tooth. The overall maximum stress of deformation was also comparable to that seen in an intact tooth. In non-threaded implants, the apical seal was highly dependent on the wedging of the implant, along with the cement used at the apical dentine interface [15]. However, with an irregular apical opening and circular implant, sealing the interface would be most difficult if not impossible. Hence the design for the endo implant used to evaluate the stress distribution in this study was used. The FEA analysis noted that all models show maximal failure on the incisal edge, which shows that the pattern of failure will not be in the apical end and hence, preventing all kinds of catastrophic failures.

Moreover for the clinical scenarios the restoration with endodontic implant helped the tooth reinforce and redistribute functional forces in a way similar to that seen in an intact tooth [16]. Hence, the novel design presented in this study provides favourable results that can be extrapolated to clinical settings after further future developments. This study has a few limitations. The main limitation is that only one model of each of the designs was compared to the intact tooth model [17]. The conditions replicated represented all the physical aspects of the materials and tooth included in an ideal setting, but not an exact representation of the oral cavity [18].

5. CONCLUSION

Endodontic implants, although having a mixed success rate in the past, are now a reliable choice for the treatment of maxillary anterior teeth, particularly in trauma cases with a poor crown: root ratio, root resorption, and apical excision. Additionally, as bioceramics advances, outcomes may be better predicted, which eventually aids in the retention of teeth in such an aesthetic zone. Future studies to be done to realise the feasibility of these designs in clinical conditions.

6. REFERENCES

1. Frank, A.L. (1967) ‘Improvement of the crown-root ratio by endodontic endosseous implants’, Journal of the American Dental Association , 74(3), pp. 451–462. Available at: https://doi.org/10.14219/jada.archive.1967.0083.
2. Sharma, S., Londhe, S., Hegde, M.N. and Sadananda, V., 2020. Biomechanical Performance of an Immature Pulpless Maxillary Central Incisor Managed with Different Modalities: A Finite Element Analysis. Global Dentistry: Case Reports, 1(1), pp.1-8.
3. Frank, A.L. and Abrams, A.M. (1969) ‘Histologic evaluation of endodontic implants’, Journal of the American Dental Association , 78(3), pp. 520–524. Available at: https://doi.org/10.14219/jada.archive.1969.0145.
4. Sri, H.K., Ahmed, N. and Sasanka, L.K., 2024. Association of Age, Gender, and Site of Implant Placement: An Institution-Based Retrospective Study. Journal of Long-Term Effects of Medical Implants, 34
5. Ingle, J.I., Bakland, L.K. and Craig Baumgartner, J. (2008) Ingle’s Endodontics 6. PMPH USA. Available at: https://books.google.com/books/about/Ingle_s_Endodontics_6.html?hl=&id=aV1kEf7mlckC.
6. Korkmaz, I.H. and Kul, E. (2022) ‘Investigation of the Type of Angled Abutment for Anterior Maxillary Implants: A Finite Element Analysis’, Journal of prosthodontics: official journal of the American College of Prosthodontists, 31(8), pp. 689–696. Available at: https://doi.org/10.1111/jopr.13462.
7. Cibikkarthik, T., Duraisamy, R., Ganapathy, D.M. and Maiti, S., 2023. Awareness On Current Status of Basal Implants Among Dental Students.
8. Larsen, R.M., Patten, J.R. and Wayman, B.E. (1989) ‘Endodontic endosseous implants: case reports and update of material’, Journal of endodontia, 15(10), pp. 496–500. Available at: https://doi.org/10.1016/s0099-2399(89)80033-0.
9. Parmar, G. and Pramodkumar, A.V. (2000) ‘Custom-fabricated endodontic implants: report of two cases’, Journal of endodontia, 26(5), pp. 301–303. Available at: https://doi.org/10.1097/00004770-200005000-00015.
10. Deshmukh, M., Ahmed, N., Sri, H., Agarwal, S. and Ganapathy, D., 2022. Evaluation Of Immediate Bone Level Changes Around Different Implant Systems From Surgical Stage To Prosthetic Stage-A Retrospective Study. Journal of Pharmaceutical Negative Results, pp.500-507
11. Piattelli, A. (2016) Bone Response to Dental Implant Materials. Woodhead Publishing. Available at: https://play.google.com/store/books/details?id=0jPZCgAAQBAJ.
12. Nallaswamy, D., 2017. Textbook of prosthodontics. JP Medical Ltd

13. Rana, V., Sharma, S., Kapri, A., Sharma, S., Jacob, O. and Nainan, O., Horizontal post-An innovative method to rehabilitate endodontically treated teeth.
14. Romanos, G. (2005) Immediate Loading of Endosseous Implants in the Posterior Mandible: Animal and Clinical Studies. Available at: https://books.google.com/books/about/Immediate_Loading_of_Endosseous_Implants.html?hl=&id=kQ5qAAAAMAAJ.
15. KUMAR, S.P., RAJESHKUMAR, S. and SIVASAMY, V., 2020. Review on gold nanoparticle used in dentistry. International Journal of Pharmaceutical Research (09752366), 12(3)
16. Sharma, S., Ramesh, S. and Rayapudi, J., 2023. Biomechanical Performance of Mandibular Molars with Deep Mesio-Occlusal-Distal Cavities Rehabilitated with Horizontal Posts: A 3D Finite Element Analysis. International Journal of Dentistry, 2023(1), p.3379373.
17. Sharma, S., Londhe, S.M., Hegde, M.N. and Sadananda, V., 2020. Are bioceramics the dernier Cri in the management of stage 4 developed root? A finite element analysis. The Journal of Contemporary Dental Practice, 21(9), pp.961-969.
18. Weine, F.S. (2004) Endodontic Therapy. Available at: https://books.google.com/books/about/Endodontic_Therapy.html?hl=&id=BdBpAAAAMAAJ.
19. Rajaraman, V., Nallaswamy, D., Ganapathy, D.M. and Ashok, V., 2021. An innovative meta-systematic review into the landscape of literature and the concluding evidence on the quality of life of patients using two implant supported mandibular complete denture prosthesis. Journal of Advanced Oral Research, 12(1), pp.7-23