Comparative Evaluation of Stress Distribution of Conventional vs Preformed Band and Loop Space Maintainer on Deciduous Molar: A 3-D Finite Element Analysis

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ABSTRACT

Background:

Timely placement of a space maintainer during the primary dentition phase is crucial for preventing future loss of arch length. Its use is essential for maintaining the necessary space to allow proper eruption and alignment of the permanent successor tooth. This study compares the stress distribution of conventional Vs preformed band and loop space maintainer on deciduous molar using finite element analysis.

Materials and methods:

The study included 3D scan of sound deciduous mandibular second molar and its supporting tissues, which were converted from CBCT DICOM to STL by using MIMICS for generating 3D geometric model. Space maintainers were fabricated on 3D models. Hypermesh was used to generate the finite element meshed models, which were imported to ANSYS software and subjected to 245 N bite force at 0 degree, 45 degree, 90 degree load. Results were obtained in the form of von Mises stress distributions.

Results:

Preformed space maintainer shown less stresses along the underlying structures compared to conventional space maintainer on crown and underlying structures. The stress patterns were within the safe range for models.

Conclusion:

Preformed space maintainer shown less stress distribution on underlying structures and hence can be used to maintain the space. FEA analysis can be used as guide to motivate parents about the importance of crown in children.

Keywords: 3D finite element analysis, Band and loop space maintainer, Preformed space maintainer.

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Introduction-

Deciduous teeth are vital to a child's general growth and development. In addition to their key roles in chewing, speech, and maintaining facial appearance, they serve an important function in directing the proper eruption and positioning of permanent teeth. The shedding of primary teeth and the emergence of permanent ones is a natural physiological process. However, this progression can be disturbed by factors such as premature loss of primary teeth, cavities between adjacent teeth, or dental trauma. When primary teeth are lost prematurely, it results in the mesial migration of adjacent teeth, resulting in a reduction of arch length. This, in turn, may cause several complications in the permanent dentition. When early tooth loss becomes unavoidable because of severe decay or another clinical factors, the most efficacious way to preserve the space and ensure proper dental development is through the use of space maintainers. Of the various available designs, the band and loop space maintainer, is one of the most frequently used due to its effectiveness and high success rate [1.] Band and loop has been used since long as a space maintainer with high success rates, but in spite of good patient compliance, disintegration of cement, solder failure, caries formation along the margins of the band and long construction time are some of the disadvantages associated with them. Hence to overcome this, over recent years, preformed band and loops have been presented to dentistry .They can be placed in a single visit, are quick to apply, do not involve laboratory procedures, save time, and are cost-effective. For prefabricated space maintainers, bands are selected according to the mesiodistal measurement of the abutment tooth. Biting and transmission chewing results in the of masticatory forces mediated along the crown structure to the teeth. Biomechanical evaluation of extracted tooth and restorative materials in vitro utilize destructive mechanical tests for analysing the tooth behaviour and provide limited information about the internal behaviour of the structures being studied. [6,7] Researchers routinely utilise three dimensional [2.] Finite Element Analysis (3-D FEA) is used to observe the stress distribution following dental restoration or prosthesis using various 3D models, and it is now widely regarded as a non-invasive and outstanding method for complex stress analysis of overlaying structures. However, very few studies have evaluated the stress distribution on deciduous molars using finite element analysis when comparing conventional band and loop space maintainers with preformed band and loop space maintainers. Therefore, the aim of this study was to evaluate the stress distribution on the supporting tooth structure and periodontium caused by preformed and conventional band and loop space maintainers in children, using a 3D finite element model.

Materials and Methodology-

The study was carried out after obtaining the written consent from the patient's guardian and by using a CBCT scan (DICOM format at 0.5 mm intervals) of a 6-year-old child with sound non-carious deciduous mandibular second molar which was taken for anterior tooth trauma evaluation during last year. Single sample per group (total two groups) were selected according to prior studies for finite element analysis of stress distribution. To carry out the study, three dimensional (3D) models of the teeth, the jaws and a band and loop space maintainer were constructed as follows.

Development of models-

After obtaining the written consent from the patient's guardian, a CBCT scan of the patient aged 6 years referred to the Department of Pedodontics was used, which was taken during previous year for maxillary anterior trauma evaluation having non carious, sound deciduous mandibular second molar tooth 19 and the tooth's data was collected in Digital Imaging and Communication in Medicine (DICOM) format at 0.5 mm intervals[3.] The 3D scan of the tooth was transformed from CBCT DICOM to stereolithographic (STL) formatted file, by using Materialise Interactive Medical Image Control System (MIMICS) for generating 3D geometric models. In the current study, the tooth was modelled with its basic parts consisted of enamel and dentin tissues. Further, a pulp chamber was constructed within the dentin core with its corresponding pulp. A periodontal ligament zone with a 0.25 mm thickness was constructed to surround the outer portion of the two roots, starting from its cemento-enamel junction (CEJ) contour. The cortical bone surrounding the cancellous bone core was 2 mm thick. Cortical and spongy bone models were prepared with the inner part representing the spongy bone with 14 mm diameter and 22 mm height, which covers the interior space of the other bone (shell of 2 mm thickness) that symbolizes cortical bone (it has an outside diameter of 16 m and height of 24 mm)[4].

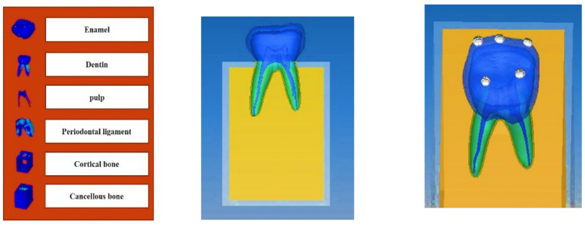


Fig 1-Showing 3D model of healthy tooth and its surrounding structures reconstructed using MIMICS

Both a conventional and a preformed band and loop space maintainer were then fabricated for the primary second molar. The tooth geometry was exported to the finite element program in the STL file format[5].

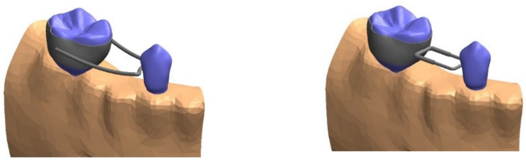


Fig 2-Showing 3D model of conventional and preformed band and loop space maintainer reconstructed using MIMICS

Groups involved in the study-

GROUP	MODEL
Group 1	Tooth model with the presence of deciduous mandibular first molar
Group 2	Tooth model with the absence of deciduous mandibular first molar
Group 3	Tooth model with conventional band and loop space maintainer.
Group 4	Tooth model with preformed band and loop space maintainer. (Kids-e-Dental, LLP, Mumbai, India)

Automatic meshing-

Finite element analysis uses a complex system of points called nodes which make a grid called mesh that represent a geometric object as a collection of finite elements. The meshed models were imported to ANSYS (Version 19.2, ANSYS Inc., Canonsburg, PA) for analysis. The Poisson's ratio, modulus of elasticity values of the materials was attributed to the model after the importation into the software[6].

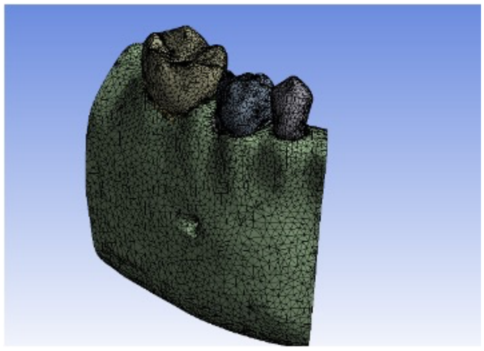


Fig 3- Meshing of teeth model using Hypermesh

Number of nodes and elements of each finite element mesh model-

Zone	Nodes	Elements
Tooth model with conventional band and loop space maintainer	418958	236787
Tooth model with preformed band and loop space maintainer	413725	234364
Tooth model of deciduous canine,first molar and second molar	557016	317257
Tooth model in the absence of deciduous first molar	387966	221816

Elastic modulus and Poisson's ratio of materials used in the model[7]-

Component	Material	Young's Modulus(MPa)	Poisson's Ratio
Cortical Bone	Elatic, Isotropic	13,700	0.30
Spongy Bone	Elatic, Isotropic	1,370	0.30
PDL	Elatic, Isotropic	0.05	0.30

Tooth	Elatic, Isotropic	20,000	0.30
Space Maintainer	Stainless Steel	193,000	0.31

Application of force-

The models received occlusal load at a constant intensity of 245 N to simulate a mastication load. The load was applied on the teeth in the occlusal contact areas in vertical, oblique and lateral fashion[8]. Three points on the outer inclines of the buccal cusps and two points on the inner inclines of the lingual cusps were loaded. The analysis was carried out in three directions 0^0 (vertical), 45^0 (oblique), 90^0 (lateral) along the long axis of the tooth[9]. The stress values and patterns due to load application was calculated based on the Von Mises dimensional criterion.

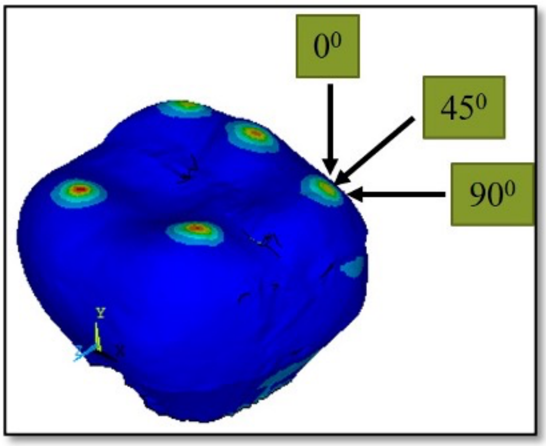


Fig 4-Loading points and directions applied on tooth model simulating masticatory forces.

Results-

The von Mises stresses were visualized in colour coding ranging from dark blue (minimum stress) to red (maximum stress).

On vertical load (0^0):

The presence of the deciduous first molar demonstrated the most favourable stress distribution pattern on the second molar and its supporting structures. Its absence resulted in increased von Mises stress values. Both conventional and preformed band and loop space maintainers reduced stress compared to the extraction condition; however, neither was able to reproduce the physiological load distribution observed in the natural dentition.

On oblique load (45^0):

A significant increase in stress was observed following premature loss of the deciduous first molar. The second molar stress nearly doubled compared to natural dentition and remained similarly elevated with both conventional and preformed band-and-loop space maintainers. Periodontal ligament stress also increased in the absence of the deciduous first molar and with space maintainers. Cortical bone stress was highest in the natural dentition model, whereas cancellous bone stress increased after tooth loss and with both space maintainers.

On lateral load (90^0):

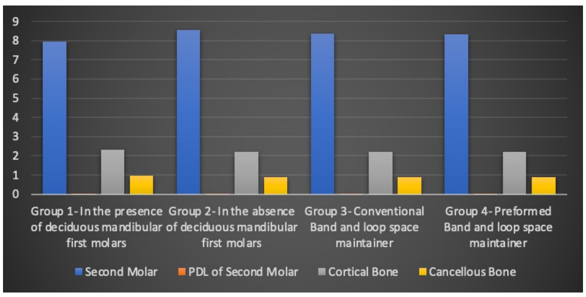
The presence of the deciduous first molar demonstrated lower stress in the second molar and periodontal ligament, whereas its absence resulted in the highest stress values, which remained similarly elevated with both conventional and preformed band-and-loop space maintainers. Cortical bone stress was greatest under natural conditions and reduced following tooth loss and space maintainer placement. In contrast, cancellous bone stress increased in the absence of the first molar and with both space maintainers compared to natural dentition.

Maximum von Mises stress on different parts of tooth and its supporting structures of deciduous mandibular second molar:

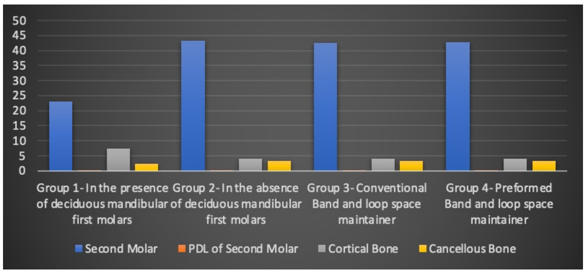
Structure	Group 1	Group 2	Group 3	Group 4
	In the presence of deciduous mandibular first molar	In the absence of deciduous mandibular first molar	With conventional band and loop space maintainer	With preformed band and loop space maintainer
Load: Vertical (0^0)				
Crown stress	7.9596	8.5614	8.3444	8.323
Periodontal ligament stress	0.001411	0.001756	0.001752	0.001755
Cortical bone stress	2.3052	2.2107	2.2103	2.2148
Cancellous	0.96871	0.87576	0.87654	0.87725

bone stress				
Load: Oblique (45^0)				
Crown stress	23.054	43.204	42.55	42.798
Periodontal ligament stress	0.005456	0.013232	0.013056	0.01314
Cortical bone stress	7.3651	3.9891	3.9712	3.9965
Cancellous bone stress	2.4495	3.3255	3.3063	3.3257
Load: Lateral (90^0)				
Crown stress	30.73	59.517	58.653	59.011
Periodontal ligament stress	0.007032	0.017873	0.017624	0.017742
Cortical bone stress	9.896	5.1936	5.1605	5.202
Cancellous bone stress	3.1205	4.413	4.3852	4.4129

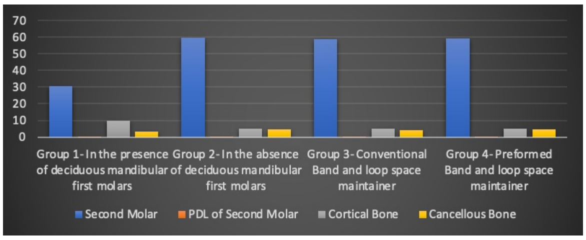
Graph 1: Von Mises stress on different parts of tooth and its supporting tissues of deciduous mandibular second molar on vertical load



Graph 2: Von Mises stress on different parts of tooth and its supporting tissues of deciduous mandibular second molar on oblique load



Graph 3: Von Mises stress on different parts of tooth and its supporting tissues of deciduous mandibular second molar on lateral load



Discussion-

Primary teeth play a fundamental role in pediatric oral development. Beyond their essential functions in mastication, phonation, and esthetics, they act as natural space maintainers, preserving arch integrity and guiding the eruption of permanent successors. Premature exfoliation of primary teeth, particularly molars can result in mesial drift of adjacent teeth, arch length reduction, crowding, and insufficient space for the eruption of permanent dentition. To prevent these sequelae, the use of space maintainers has become a well-established preventive strategy in pediatric dentistry[10].

Uddanwadiker et al. (2013) reported that among band and loop, Nance, and transpalatal arch appliances, the Nance appliance exhibited the least stress distribution and minimal deformation of supporting structures under simulated masticatory forces in a 3D finite element analysis[11].

In contrast, the current study found that the presence of the deciduous first molar resulted in the least stress distribution to supporting structures, highlighting the biomechanical advantage of maintaining the primary tooth.

Rentes AM et al. (2002) and Prabhakar AR et al. (2015) reported that in the primary dentition the biting forces range between 161-330N and considered 245N as an average force. Therefore, in this study a force of 245 N was applied to each model to simulate normal physiologic masticatory conditions[12,13].

In this study, the findings suggested that the loading of lateral forces results in the highest overall stress distribution when a conventional band and loop space maintainer is used. In contrast, the presence of deciduous first molar is associated with the lowest levels of stress distribution. On the other hand, periodontal ligament shows highest amount of stress distribution when force is loaded laterally whereas lowest amount of stress is distributed with presence of deciduous first molar. The study conducted by Shi H et al (2024) showed similar results where author evaluated stress distribution on enamel, periodontal ligament and bone of deciduous second molar using 3D finite element analysis[14].

The finite element method is sometimes viewed as a less time-consuming process than experimental research, and therefore could minimize laboratory testing requirements. Due to the complexity of shape, properties, and boundary conditions of dental structures, comprehensive modelling can also quickly become very complex and time-consuming. FEA is the compilation of our understanding of physical laws and material properties, expressed in a theoretical model that describes the interactions between various factors.

Conclusion-

The retention of deciduous mandibular first molars plays a pivotal role in optimizing the biomechanical behavior of the masticatory system. Finite Element Analysis (FEA) consistently shows that natural dentition displays the lowest von Mises stresses in the second molar, periodontal ligament (PDL), and cancellous bone across various loading angles (0°, 45°, and 90°), indicating more efficient load dissipation and enhanced biomechanical stability.

Conversely, cases involving absence of deciduous mandibular first molar and presence of both conventional and preformed space maintainers result in markedly higher stress values, particularly under oblique and vertical loading. This reflects compromised biomechanical performance, as the absence of the deciduous molar leads to altered force distribution and increased stress concentrations in adjacent structures.

These findings are crucial for clinical decision-making, emphasizing the importance of preserving deciduous molars when possible to ensure optimal biomechanical function and reduce the risk of long-term dental complications.

References-

1. Setia V, Pandit IK, Srivastava N, Gugnani N, Sekhon HK. Space maintainers in dentistry: past to present. J Clin Diagn Res. 2013 Oct;7(10):2402-5. doi: 10.7860/JCDR/2013/6604.3539. Epub 2013 Oct 5. PMID: 24298544; PMCID: PMC3843386.
2. Jayachandar D, Gurunathan D, Jeevanandan G. Prevalence of early loss of primary molars among children aged 5-10 years in Chennai: A cross-sectional study. J Indian Soc Pedod Prev Dent. 2019 Apr-Jun;37(2):115-119. doi: 10.4103/1319-2442.261340. PMID: 31249172.
3. Abuelenain DA, Ajaj R, El-Bab EI, Hammouda MM. Comparison of Stresses Generated within the Supporting Structures of Mandibular Second Molars Restored with Different Crown Materials: 3-D Finite Element Analysis (FEA). Journal of Prosthodontics. 2015 Aug;24(6):484-93.
4. Hegde K, Suvarna R, Bhat S. Stress analysis in endodontically treated primary molar with and without stainless steel crown: A comparative finite element model study. Journal of Natural Science, Biology and Medicine. 2019 Jul 1;10(2):202.
5. Waly AS, Souror YR, Yousief SA, Alqahtani WM, El-Anwar MI. Pediatric stainless-steel crown cementation finite element study. European Journal of Dentistry. 2021 Feb;15(01):077-83.
6. Allen C, Meyer CA, Yoo E, Vargas JA, Liu Y, Jalali P. Stress distribution in a tooth treated through minimally invasive access compared to one treated through traditional access: A finite element analysis study. Journal of Conservative Dentistry: JCD. 2018 Sep;21(5):505.
7. Desai Shrikar R, Shinde Harshada H. Finite Element Analysis: Basics and Its Applications in Dentistry. Indian Journal of Dental Sciences. 2012 Mar 1;4(1).
8. Kirzioglu Z, Ceyhan D, Sengul F, Altun AC. Three-dimensional finite element analysis of the composite and compomer onlays in primary molars. Computer Methods in Biomechanics and Biomedical Engineering. 2019 Apr;22(10),936-941.
9. Hegde K, Suvarna R, Bhat S. Stress analysis in endodontically treated primary molar with and without stainless steel crown: A comparative finite element model study. Journal of Natural Science, Biology and Medicine. 2019 Jul 1;10(2):202.

10. Tunc ES, Bayrak S, Tuloglu N, Egilmez T, Isci D. Evaluation of survival of 3 different fixed space maintainers. *Pediatr Dent*. 2012;34(4)
11. Uddanwadiker R, Patil PG**.** Evaluation of the deformations on the jaw bone due to a band and loop, Nance appliance and trans-palatal arch space-maintainers: a three-dimensional finite element analysis. *Dentistry*. 2013;3:172.
12. Prabhakar AR, Yavagal CM, Chakraborty A, Sugandhan S. Finite element stress analysis of stainless steel crowns. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2015 Jul 1;33(3):183
13. Rentes AM, Gavião MB, Amaral JR. Bite force determination in children with primary dentition. Journal of Oral Rehabilitation. 2002 Dec;29(12):1174-80.
14. Thakur B, Bhardwaj A, Luke AM, Wahjuningrum DA. Effectiveness of traditional band and loop space maintainer vs 3D-printed space maintainer following the loss of primary teeth: a randomized clinical trial. Scientific Reports. 2024 Jun 18;14(1):14081.