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Research Protocol

Dentistry Section

Comparative Evaluation of Three-dimensional Skeletal and Dentoalveolar Effects of Sawangi Flexiforce Expander and NiTi Expander in Class II (vertical) Cases with Maxillary Constriction: A Research Protocol

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ABSTRACT

Introduction: Maxillary constriction is a very common type of malocclusion found at any age. It is recommended to treat it as early as possible to avoid the worsening of the situation and to re-establish optimal function and aesthetics. Expansion of the maxillary arch is considered the best treatment procedure in a growing child. There are various appliances used for the expansion of the arch. The Nickel Titanium (NiTi) expander is considered the hallmark in orthodontics, but it has a few drawbacks. To overcome these drawbacks, the Sawangi Flexiforce Expander (SFE) has been introduced. The present study aims to evaluate and compare the effects of SFE against NiTi expander.

Need for the study: The commercially available NiTi expander is very expensive. As most dental practices are located in rural areas, not every patient requiring arch expansion can afford it. Therefore, there is a need for an appliance that is as effective as the NiTi expander but affordable for everyone.

Aim: To evaluate and compare the three-dimensional skeletal and dentoalveolar effects of SFE against the NiTi expander in class II (vertical) cases with maxillary constriction using the Finite Element Method (FEM).

Materials and Methods: The present FEM study will be conducted in the Department of Orthodontics and Dentofacial Orthopaedics at Sharad Pawar Dental College in Wardha, Maharashtra, India. The study will take place from November 2023 to October 2024. A single patient with a vertically growing pattern will be selected for a Computed Tomography scan (CT scan) of the Nasomaxillary complex based on inclusion and exclusion criteria. The CT scan of the patient will then be converted into a 3D finite element model. The 3D models of the NiTi expander, SFE, and nasomaxillary complex will be studied to evaluate and compare the three-dimensional effects. Parameters such as stress distribution and displacement at skeletal, dental, and dentoalveolar landmarks of the nasomaxillary complex in three directions due to both expanders will be evaluated. An unpaired t-test will be used to determine significant differences between the two expanders and to compare the outcomes. The displacement at each landmark due to 1 mm of activation of both expanders will be correlated using the Pearson's correlation test. A p-value <0.05 will be considered significant.

Keywords: Finite element method, Maxillary Constriction, Posterior crossbite, Slow maxillary expansion, Sawangi flexiforce expander

INTRODUCTION

In Orthodontics, maxillary constriction refers to reduced maxillary width in transverse dimensions. When the maxilla and mandible do not have a proper transverse relationship, the patient may experience cervical wear (abfraction), dental arch crowding, and a negative impact on their smile and airways [1,2]. This is a common problem regardless of age. Clinically, maxillary constriction is characterised by a narrow maxillary arch and crowding [3]. Maxillary constriction is generally associated with class II malocclusion, class III malocclusion with a hypoplastic maxilla, and cleft lip and palate. In most cases, a constricted maxillary arch presents as a posterior crossbite. A crossbite can be anterior or posterior and may be unilateral or bilateral. The prevalence of posterior crossbite is 0.99% among the Indian population [4].

Correction of transverse plane discrepancies typically involves palate expansion through a combination of Orthopaedic and orthodontic tooth movements [5]. Expansion is usually the primary treatment option for correcting skeletal defects of the maxilla. Rapid maxillary expansion is a skeletal expansion method that involves separating the mid-palatal suture [6], resulting in the movement of the two maxillary halves away from each other. Rapid maxillary expansion appliances exert significant force at the suture site over a short period. The activation rate of these appliances is faster and primarily elicits an Orthopaedic response [7]. Expansion can be achieved using removable or fixed appliances. Several side-effects have been associated with this procedure, including pain, relapse, molar inclination, bone loss, gingival recession, and root resorption [8]. Due to the substantial force applied in rapid maxillary expansion, these appliances may cause discomfort and require increased patient co-operation. Expansion achieved over a short period is more susceptible to relapse [9].

In slow maxillary expansion, the arch is expanded at a slower rate. Studies have shown that slow expansion produces the best physiological changes, including orthodontic movements [8,9]. These appliances apply light and continuous force, providing greater comfort for patients and eliminating the need for frequent activation. Due to the consistent force, there are fewer chances of relapse as the continuous stimulus to the mid-palatal suture is maintained.

The NiTi expander is commonly used for slow palatal expansion. It generates optimal and constant expansion forces. The central component is made from a thermally activated Nickel-Titanium alloy, while the rest is constructed from stainless steel. These expanders available in various prefabricated sizes [7]. However, clinical customisation is often necessary based on individual patient needs, which is not feasible with the NiTi expander.

The SFE (Sawangi Flexiforce Expander) is a novel appliance designed for achieving transverse expansion of the maxilla. It applies light and continuous force over an extended period. The expander is fabricated using 0.8 mm stainless steel wire featuring a central helix and two loops. A universal plier is utilised for the expander's fabrication. The active arm's distal portion is soldered to the molar bands. Activation of the central helix facilitates anterior expansion, while activating the loops promotes posterior expansion of the palate. In comparison to the NiTi expander, the SFE is a customised appliance made from stainless steel wire, offering a more cost-effective option. It is more flexible than other expanders and allows for simultaneous or separate anterior and posterior expansion as needed, providing an advantage over other expanders. However, the SFE requires a high level of technique sensitivity and clinician wire bending skill due to the precise wire bending required, which may be a disadvantage compared to other expanders.

Finite Element Method (FEM) is a well-recognised computerised option for addressing challenging issues in the engineering field, as well as in medical and dental research. This method has proven advantageous as it aids in planning various experimental treatment procedures without the need to involve animals or humans. In literature, this method has been successfully utilised to analyse the effects of expansion on craniofacial bones and dentition, providing exact stress and strain values on craniofacial structures that may not be achievable through clinical studies [10].

In literature, numerous studies have been conducted to assess and compare different expansion appliances using various methods, but only a few studies have utilised the FEM [10]. Due to the scarcity of such studies, the current study will be undertaken. The aim of this study is to evaluate, compare, and correlate the three-dimensional skeletal and dentoalveolar effects of the SFE compared to the NiTi expander in class II (vertical) cases with maxillary constriction using FEM.

Primary objectives: To evaluate the three-dimensional displacement at skeletal and dentoalveolar landmarks using the SFE and NiTi expander in class II (vertical) cases with maxillary constriction using FEM and to evaluate the stress patterns in different maxillary sutures produced by the SFE and NiTi expander in class II (vertical) cases with maxillary constriction using FEM.

Secondary objective: To compare and correlate the three-dimensional skeletal and dentoalveolar effects and stress patterns in different maxillary sutures produced by the SFE and NiTi expander in class II (vertical) cases with maxillary constriction using FEM.

Null hypothesis: The null hypothesis states that the SFE will demonstrate similar effects to the NiTi expander in terms of the amount of displacement in all three planes and stress values at maxillary sutures.

Alternative hypothesis: The alternative hypothesis suggests that the SFE will not show similar effects compared to the NiTi expander in terms of the amount of displacement in all three planes and stress values at maxillary sutures.

REVIEW OF LITERATURE

This study will help authors to compare the three-dimensional effects of the SFE on the nasomaxillary complex compared to the NiTi expander.

Kapadia RM et al., conducted a finite element study to compare the effects of the Jackscrew, Quad Helix, and NiTi Expander-2 on the maxillary bone of young patients. The study was carried out on an analytical model of a dry human skull with mixed dentition. Significant differences were observed in the effects of all appliances. The Jackscrew produced the greatest transverse deformation in the dental region and anteroposterior deformation in the dentoalveolar region. The Jackscrew induced the highest amount of stress, while the Quad Helix and NiTi Expander produced the same amount of stress and strain [10].

Kumar A et al., conducted a study that assessed stress distribution and displacement in the craniofacial region due to the Quad Helix and NiTi Expander-2 (NPE2) using a 3D finite element model. Both appliances generated the highest stress at the mid-palatal suture, along with maximum posterior displacement. The frontozygomatic structure was the second-highest area of stress distribution. Both appliances exhibited a similar pattern of stress distribution, but NPE2 produced less magnitude of stress than the Quad Helix. A significant difference was observed at the pterygomaxillary suture, where the Quad Helix showed high stress, while NPE2 produced little to no stress [11].

Shetty P et al., assessed the stress distribution pattern on the maxillary complex due to expansion by the Slow Maxillary Expansion Plate and Nitinol Palate Expander 2. They observed tipping movement at the posteriors in the finite element model due to the Jackscrew and maximum displacement at the molar region due to NPE2. Both appliances exhibited different areas of stress concentration, such as the palatal bone beside the central incisors for the Jackscrew and the midpalatal suture for NPE2 [12].

Nagrik AP and Bhad WA compared the effectiveness of the Transforce Transverse Appliance (TTA) and the Nickel-Titanium Palatal Expander (NPE) on arch expansion. A total of 20 patients with skeletal Class II malocclusion and constricted maxillary arches were assessed for transverse interdental width, skeletal expansion, alveolar tipping, molar rotation, the ratio of inter-canine to inter-molar change, and the rate of expansion using study models and lateral cephalograms. Both appliances led to significant changes in transverse arch dimensions, but no significant differences were observed in the inter-group comparison except for the expansion rate. The rate of expansion with the NPE was more significant than with the TTA [9].

If both expanders demonstrate a similar amount of expansion, it would be advantageous to use the Sawangi Flexiforce Appliance for expanding the maxillary arch due to its affordability and chair-side fabrication.

MATERIALS AND METHODS

The finite element study will be conducted in the Department of Orthodontics and Dentofacial Orthopaedics at Sharad Pawar Dental College, Sawangi (M), Wardha, Maharashtra, India, from November 2023 to October 2024. The Ethical Approval for the study has been obtained from the Institutional Ethics Committee {DMIHER(DU)/IEC/2023/574}.

A single patient will be selected from those attending the Outpatient Department (OPD) of the Orthodontics and Dentofacial Orthopaedics Department. A patient with skeletal Class II malocclusion and a vertical growth pattern will be selected for a CT scan of the nasomaxillary complex. The parents of the patient will be asked to consent to the CT scan after clarifying the research aims and objectives.

Inclusion criteria:

- Class II malocclusion with functional retrusion of the mandible.
- Patients with a constricted maxilla with or without a posterior crossbite.
- Patients with a vertical growth pattern.
- Pubertal age patients.

Exclusion criteria:

- Patients with a wide mandibular arch width (Class III).
- Patients with craniofacial deformities.
- Patients with a history of previous orthodontic treatment.
- Patients with a history of any trauma or surgery.

A three-dimensional finite element model will be developed after scanning the nasomaxillary complex of the patient. Initially, the patient will undergo a CT scan, and the generated image of the nasomaxillary complex will be converted into Digital Imaging and Communications in Medicine (DICOM) format. The geometric model will then be created using the DICOM image. The NiTi expander will be modeled using values from the literature, while the SFE will be modeled after evaluating the values. Subsequently, a finite element model will be created based on the geometric model. Material properties will be assigned by incorporating data from the literature concerning the Young's modulus and the Poisson's ratio. Boundary conditions will be applied to the model, defined based on the nature of the modelling system. Forces will be incorporated at different points of the geometry and their configuration. The designs of both expanders will be programmed in the software, and then both expanders will be activated according to standard protocols. The activated expander will exert stress and cause displacement in different parts of the nasomaxillary complex.

Von Mises stress distribution in MPa and displacement in millimetres (mm) will be studied at the following landmarks of the nasomaxillary complex model using FEM.

Dental landmarks:

a. Contact point between central incisors
b. Cusp tip of canines
c. Central pit of first permanent molars
d. CEJ of central incisors, canines, and first permanent molars

Dentoalveolar landmarks:

a. Apical region of central incisors
b. Apical region of canines
c. Apical region of first permanent molars

Skeletal landmarks:

a. Mid-palatine suture- anterior tip and posterior tip
b. Anterior nasal spine
c. Nasal septum
d. Internasal suture
e. Nasomaxillary suture
f. Frontonasal suture
g. Frontomaxillary suture
h. Zygomaticomaxillary suture
i. Zygomaticofrontal suture
j. Zygomaticotemporal suture
k. Pterygomaxillary suture

Outcome:

- Von Mises stress distribution (MPa)
- Displacement (mm) at each landmark.

Primary outcome: The displacement of dental, dentoalveolar and skeletal components occurred when subjected to activated SFE will be comparable to the effects of NiTi expander.

Secondary outcome: The values of stress distribution produced by activated SFE and NiTi expander at each selected dental, dentoalveolar and skeletal landmark will be comparable.

STATISTICAL ANALYSIS

The Von Mises stress distribution pattern and displacement will be noted at all landmarks in three-dimensional planes and analysed statistically using Software-R. The raw data will be statistically compared using an unpaired t-test to find any significant differences between the outcomes of the two expanders. A Pearson's correlation test will be used to correlate the displacement at each landmark that occurred due to each 1 mm of activation of both expanders at a 0.5% level of significance.

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