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"Evaluation and Comparison of Stress and Displacement Using Slow and Rapid Maxillary Expansion in Cleft Palate - A Three Dimensional Finite Element Study"

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Abstract:
Introduction*: The purpose of this study was to evaluate and compare the stress and displacement pattern using slow and rapid maxillary appliance in unilateral cleft palate.*
Materials and Methods: *Three finite element model of a young human skull with Cleft Lip and Palate (CLCP) was generated using data from 3D scans of a dried young skull. models of skull and maxilla with unilateral cleft palate with extensions into alveolus, alveolus and premaxilla, alveolus, premaxilla and hard palate, surrounding structures were modelled using the Solidworks software.*
The model was then strained to a state of maxillary expansion with the application of 2N and 7N forces to simulate slow and rapid expansion forces. The three-dimensional pattern of displacement and stress distribution were then analyzed.
Results: *The results of the present study indicated that the transverse orthopaedic forces not only produced an expansive force at the midpalatal suture but also produce high forces at various structures on the craniofacial complex, particularly the sphenoid and zygomatic bones.This study also revealed that in the presence of a continuous cleft in the jaw and palate area, slow expansion orthodontic forces (quadhelix) already suffice to bring about a skeletal widening of the maxilla. As the extent of the cleft increased and the length of the suture decreased the amount of forces required to bring about expansion is less.*
Conclusion: *This study equips the clinician with the knowledge of the magnitude of the displacement and the stress pattern during maxillary expansion in the various areas of the craniofacial region in patients with varying extent of CLCP. Maxillary expansion using slow expansion therefore represents a reasonable alternative to using conventional rapid maxillary expansion among cleft patients.*
Key Word*: Slow Maxillary expansion, Rapid maxillary expansion, Finite element method*

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I. Introduction

Cleft lip and palate (CLP) is the most common congenital defect involving the face and jaws; about 1 child in 700 children is born with the condition. The cleft disrupts the structural integrity of the palate and results in medio-lingual rotation of the minor segment of the maxilla.[1]

In growing patients without oral clefts, rapid maxillary expansion (RME) corrects maxillary constriction and posterior crossbites by opening the midpalatal suture[2]. RME effect results in transverse bone gains increasing the maxillary dental arch perimeter and the buccal inclination of the maxillary first permanent molars and producing slight buccal bone changes.[3]

On the other hand, it has been suggested in the literature that slow maxillary expansion (SME) shows essentially dentoalveolar effects, with smaller orthopedic repercussions in the maxillary base, more bodily displacement of maxillary first permanent molars compared to RME, and greater buccal bone loss compared to rapid maxillary expansion.[4]

Since each treatment modality has advantages and disadvantages, controversy regarding the use of each exists.

Literature search reported limited studies describing the magnitude of the forces delivered by the appliance. Thus the clinical application of the procedure has required the operator to deliver an unknown amount of force to an unknown resistance and the activation schedules employed are largely empirically derived.

The finite element method, which has been applied in the mechanical analysis of stresses and strains in the field of engineering, makes it practicable to elucidate the biomechanical state variables such as displacements, strains and stresses induced in living structures by various external forces. [5]

The purpose of this study was to evaluate and compare the stress distribution and displacement in the mid palatal suture area, region of cleft and dentition using slow and rapid maxillary expansion using finite element analysis.

II. Material And Methods

Study Design: Finite Element Study

Methodology

A computed tomographic scan of a patient with unilateral cleft lip and palate was obtained as a requisite for pre-treatment record Then, the CT scan of the maxilla along with the teeth and circum-maxillary sutures was converted into a 3D model for finite element (FE) modelling.

Another two copies of the model were manually modified to build the cleft models mimicking Unilateral cleft palate extending into alveolus, premaxilla and UCAP (unilateral cleft of lip/alveolus/palate)

This geometric model in STL format was imported into a meshing software called **Hypermesh**. The FE model was imported into ANSYS software (version 14.5), and various considerations are established. The finite element models consisted approximately of 625000 tetrahedral elements 9,55000 Nodes and 3 degrees of freedom.

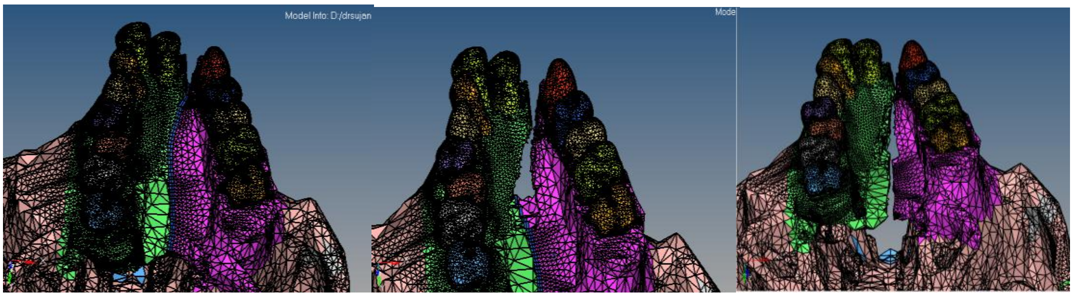

Figure 1: Basal view of the FEM model of a skull with unilateral cleft palate extending into the alveolus, palate extending into the alveolus and premaxilla, and with complete unilateral cleft palate extending into the alveolus, premaxilla and hard palate

In this study, three analytical models of skull and maxilla of unilateral cleft with cleft extensions into alveolus (Model 1), cleft extending into alveolus and premaxilla (Model 2), complete unilateral cleft with extensions into alveolus, premaxilla and hard palate (Model 3) were constructed.

Simulating slow expansion

For applying the transversely acting forces of the tooth borne slow expansion device like quad helix, the first upper molars were considered in the model. For all comparative calculations, an orthodontic transverse force of 2 N was applied to each palatal side of the first upper molars.

Simulating rapid expansion

For applying the transversely acting forces of the tooth borne rapid expansion device like HYRAX appliance, expansion was simulated by applying force on the first upper premolars and molars in the model. For all comparative calculations, an orthodontic transverse force of 7N to 10N was applied to each palatal side of the first premolars and first upper molars, which corresponded to the force delivered by a moderately activated HYRAX apparatus.

Except for the anatomical cleft form, all experimental conditions were kept constant with all calculations. (Table 1). After completion of the calculations, the comparative expansions appearing (in strain) were recorded in tabular form.

The sequential application of the above steps leads to a system of algebraic equations where the nodal displacements are unknown. These equations were solved by frontal solver technique present in the **ANSYS** workbench software.

TABLE 1. Young's modulus and Poisson's ratio for various materials used in this study (Tanne et al)[34]		
Material	Young's Modulus	Poisson's Ratio
Tooth	2.0×10^3 kg/mm2	0.3
Compact bone	1.37×10^3 kg/mm2	0.3
Maxilla	21400 MPa	0.31
Sutures	500 MPa	0.3

III. Results:

Three FEM model of the skull with CLCP extending into alveolus, alveolus and premaxilla, and complete unilateral cleft was created and slow expansion force of 2N and rapid expansion force of 7N to simulate the transversely acting forces of the quadhelix and hyrax appliance.

The results of the present study using the three-dimensional FEM of a human skull indicated that the transverse orthopaedic forces not only produced an expansive force at the midpalatal suture but also produce high forces at various structures on the craniofacial complex, particularly the sphenoid and zygomatic bones.

Stress patterns in slow expansion seen in comparison within the three models

In Model 1, Highest stress was present at the alveolar region near the premolar and molar which was found to be 2.9 N/mm^2.

The stress at the midpalatal suture is 12.3 N/mm$^{2.}$ Moderate stress found on the Frontonasal suture, Frontomaxillary suture, Nasomaxillary suture. Low stress found on the Pterygomaxillary suture and Frontozygomatic suture. Rest of the articulation showed least amount of stresses.

In model 2, Highest stress of 11.8N/mm^2 was present at the mid palatal suture. High stress was found on the Frontonasal suture, Frontomaxillary suture, Nasomaxillary suture. Moderate stress found on the Pterygo-maxillary suture and Frontozygomatic suture. Rest of the articulation showed least amount of stresses.

In model 3, The amount of stress experienced by model 3 was much lesser compared to the other two models as the integrity of the palate is compromised and the lack of midpalatal suture allows for greater ease of expansion with minimal stress.

Stress patterns in rapid expansion seen in comparison within the three models

In model 1, Highest stress of 50.7 N/mm^2 was present at the crowns of the posterior teeth. The mid-palatal suture showed a stress of 21.6N/mm^2. High stress found on the Frontonasal suture, Frontomaxillary suture, Nasomaxillary suture. Moderate stress found on the Pterygo-maxillary suture and Frontozygomatic suture. Rest of the articulation showed least amount of stresses.

In Model 2, Highest stress of 50.6 N/mm^2 was present at the crowns of the posterior teeth. The mid-palatal suture showed a stress of 20.6 N/mm^2.

The amount of stress experienced by model 3 was much lesser compared to the other two models as the integrity of the palate is compromised and the lack of midpalatal suture allows for greater ease of expansion with minimal stress.

Displacement patterns in slow expansion seen in comparison within the three models

When a transverse force of 2 N was applied to each palatal side of the first upper molars, which corresponded to the force delivered by a moderately activated quadhelix apparatus. In model 1, Skeletal displacement of 0.474 mm was noticed at the incisal edge of upper central incisor.

In model 2, Skeletal displacement was higher compared to model 1 and 0.51 mm was noticed at the incisal edge of upper central incisor. Maximum displacement of 0.511 mm was seen in the crowns of the anterior teeth.

In model 3, Skeletal displacement was higher compared to model 2 and 0.524 mm was noticed at the incisal edge of upper central incisor.

Displacement patterns in rapid expansion seen in comparison within the three models

When a transverse force of 7N to 10N was applied to each palatal side of the first premolars and first upper molars, which corresponded to the force delivered by a moderately activated HYRAX apparatus, amount of displacement for various cranial bones are listed in Table 3.

Table 2: Magnitude of von mises stress at the various circum maxillary sutures among the 3 models with slow and rapid expansion protocol (in N/mm^2)

	MODEL 1		**MODEL 2**		**MODEL 3**	
SUTURES	**RAPID EXPANSION**	**SLOW EXPANSION**	**RAPID EXPANSION**	**SLOW EXPANSION**	**RAPID EXPANSION**	**SLOW EXPANSION**
FRONTONASAL SUTURE	0.83	0.474	0.98	0.56	0.116	0.664
FRONTOMAXILLARY SUTURE	0.83	0.474	0.98	0.56	0.116	0.664
FRONTOZYGOMATIC SUTURE	0.5	0.19	0.33	0.35	0.306	0.005
INTERNASAL SUTURE	0.83	0.474	0.98	1	0.116	0.664
NASOMAXILLARY SUTURE	0.8	0.47	0.98	0.56	0.116	
ZYGOMATICOMAXILLARY SUTURE	1.12	0.64	1.12	0.63	1.13	0.64
TEMPEROZYGOMATIC SUTURE	0.26	0.19	1.11	0.27	.494	0.28

Table 3: Magnitude of displacement at various cranial structures among the 3 models with slow and rapid expansion protocol (in mm)

	MODEL 1		MODEL 2		MODEL 3	
STRUCTURES	RAPID EXPANSION	SLOW EXPANSION	RAPID EXPANSION	SLOW EXPANSION	RAPID EXPANSION	SLOW EXPANSION
SKELETAL OPENING						
Mid palatal suture	0.83	0.47	0.895	0.51	0.918	0.524
SKELETAL DISPLACEMENT AT THE CRANIAL BONES						
MAXILLARY BONE						
a) Alveolar process	0.83	0.47	.783	0.51	0.918	0.524
b) Zygomatic process	0.10	0.158	0.447	0.170	0.459	0.175
SPHENOID BONE						
a) Pterygoid plate	0.369	0.216	0.559	0.284		0.291
NASAL BONE						
a) Lateral wall of the nasal cavity	0.207	0	.335	0	.459	0
b) Medial wall of the nasal cavity	0.103	0.05	.223	0.056	.344	0.058
ZYGOMATIC BONE						
a) Maxillary process	.207	0.158	.335	0.171	0.344	0.17
b) Frontal process	0.103	0.52	0.111	0.56	0.114	0.58
c) Temporal process	0.103	0.52	0.111	0.56	0.114	0.58
d) Body	0.207	0.105	0.223	0.113	0.229	0.116

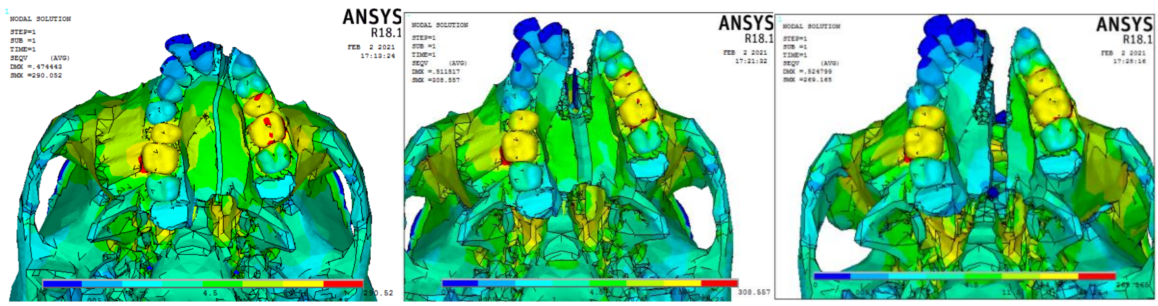

Figure 2: Pattern of Stress Distribution on the midpalatal suture after application of slow expansion force in Model 1, Model 2 and Model 3

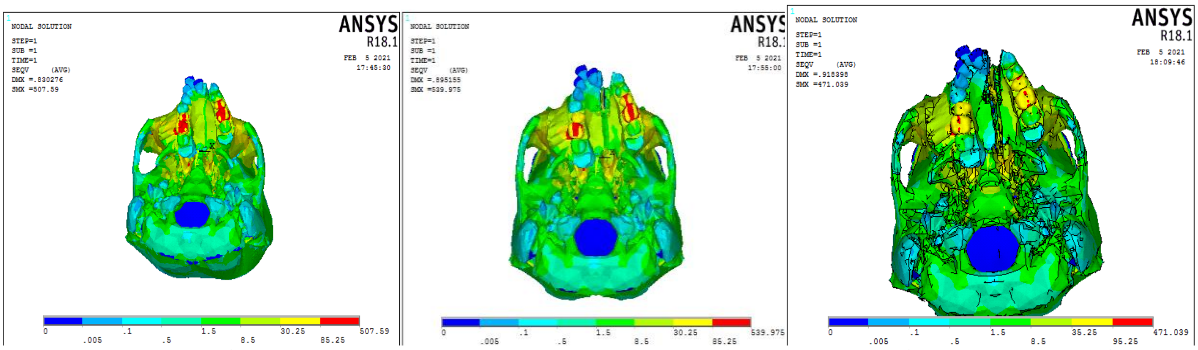

Figure 3: Pattern Of Stress Distribution on the midpalatal suture after application of Rapid expansion force in Model 1, Model 2 and Model 3

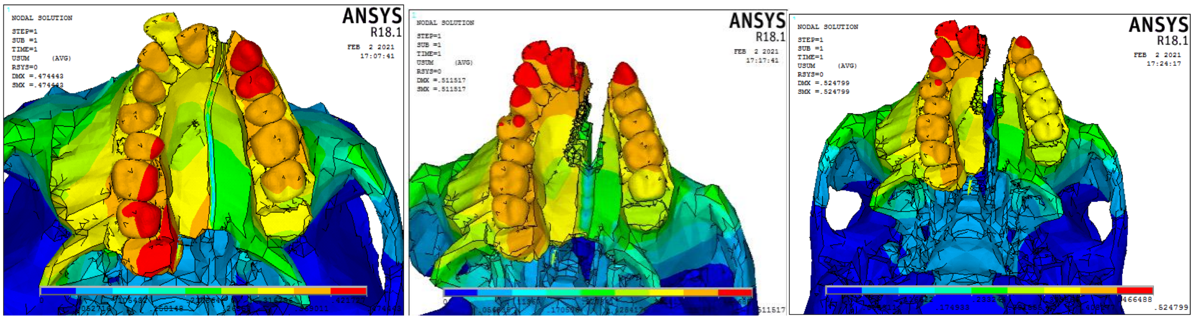

Figure 4: Skeletal Opening at the Mid Palatal Suture after slow expansion in Model 1, Model 2, Model 3

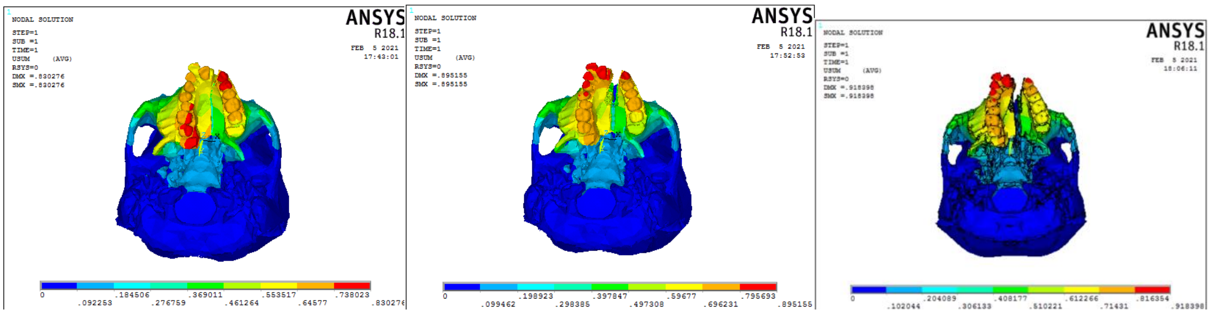

Figure 5: Skeletal Opening at the Mid Palatal Suture after Rapid expansion in Model 1, Model 2, Model 3

IV. Discussion

Dentoskeletal effects of slow and rapid maxillary expansions in growing patients without oral clefts are well documented in the orthodontic literature.[6,7] There are differences in the expansion outcomes between patients with and without the integrity of the palate. Though both the rapid and slow expansion protocol could clinically achieve expansion, the magnitude of force required to bring about expansion in a cleft palate may vary. The FEM is a well-proven and efficient mathematic instrument for evaluating orthodontic concerns and analyzing the effects of expansion devices on the craniofacial complex in a noninvasive manner. Hence in this study we evaluated and compared the stress and displacement pattern using slow and rapid maxillary appliance in unilateral cleft palate.

With finite element analysis, the point of application, magnitude, and direction of a force can be adjusted to simulate clinical situations, and the amount of stress experienced at any point can be theoretically measured.

Comparisons of the stress levels of internal structures between the cleft and non-cleft sides can then be made so that optimal points of force application for maximum anterolateral expansion of the minor segment can be predicted. Over the past years, simulation models of the facial model have improved in geometric precision.

The FEM of the skull in a study by **Iseri et al**[5] in **1998** consisted of 2349 individual elements, and an increase in the geometric precision was observed in a 2003 study by **Jafari et al** [8] that introduced a model with 6951 elements. In 2007, **Holberg et al** [9] used a simulation model of the facial skull and cranial base that consisted of approximately 30,000 elements and 50,000 nodes.

In this study, when transverse forces were applied at the maxillary, the minor and major segments of the maxilla along the cleft site were separated, and the largest transverse displacement was produced at the cusp tips of the maxillary canines. The expansion of the minor and major segments resulted in a pyramidal opening on the side of the cleft with the base of the pyramid at the floor of the nasal cavity and the apex slightly above the frontonasal suture.

The findings of this study correlate with the study done by **Gautam P et al** [10] in 2011wherein they assessed the skeletal and dental effects of rapid maxillary expansion in a patient with unilateral cleft deformity of secondary palate and alveolus using the finite element method. The study concluded that The typical wedge-shaped opening that occurs after RME, seen in non-cleft.

In this study, The maxilla moved anteriorly and downward and rotated clockwise in response to RME. The pterygoid plates were displaced laterally. The distant structures of the craniofacial skeleton—zygomatic bone, temporal bone and frontal bone—were also affected by transverse orthopedic forces. The center of rotation of the maxilla in the X direction was somewhere between the lateral and the medial pterygoid plates. In the frontal plane, the center of rotation of the maxilla was approximately at the superior orbital fissure. The maximum von Mises stresses were found along the frontomaxillary, nasomaxillary, and frontonasal sutures.

In the present study, we demonstrated that the pattern of stress distribution was different at the various craniofacial sutures in response to RME and SME.

This study is unique because 3 simulated models with varying extents of cleft were used to analyze the stress distributions within the craniofacial complex of a patient with UCLP based on the directions of the forces to obtain optimal palatal expansion.

Holberg et al[9]. in their finite element study has reported that RPE can produce up to 120 N of force and suggested that slow expanders with forces of about 5 N will suffice to bring about the necessary skeletal expansion in cleft patients. However, in the present study, we applied about 5 N of force in the FE model for slow expansion, 10 N for rapid expansion and evaluated the stress distribution around the cleft palate area and the circum-maxillary sutures.

High magnitude forces used in RPE maximize skeletal separation of midpalatal suture by overwhelming the suture before any dental movement or physiological sutural adjustment can occur. Hence, advocates of rapid maxillary expansion believe that it results in minimum dental movement (tipping) and maximum skeletal movement.[11]

The disadvantage of using rapid palatal expanders include discomfort due to traumatic separation of the midpalatal suture, inability to correct rotated molars, requirement of patient or parent cooperation in activation of the appliance, bite opening, relapse, micro trauma of the temporomandibular joint, root resorption, tissue impingement, pain and labor intensive procedure in fabrication of the appliance.[12] Advocates of slow expansion appliances have questioned the need of such large rapid forces for sutural separation. They believe that there is more physiologic adjustment to sutural separation producing greater stability and less relapse potential when using slower expansion.[13,14]

Slow palatal expansion (SPE) procedures produce less tissue resistance around the circum-maxillary structures and therefore improve bone formation in the intermaxillary suture, which should theoretically eliminate or reduce the limitation of rapid palatal expansion (RPE).[15]

In CLP patients, the palatal suture system is disturbed and either irregular or absent. These factors allow an orthopedic response to Quad helix expansion. Other authors have also noted that skeletal resistance in the transverse direction is reduced in cleft palate patients because of the special anatomical situation in the jaw and palate area.[16,17,18]

Bell et al found the average increase between the maxillary cuspids and first molar to be 3.62 mm and 6.70 mm, respectively. They theorized that part of the increase in maxillary intermolar width was due to facial tip of molars.[19]

For applying the transversely acting forces of the slow and rapid expansion protocol an orthodontic transverse force of 2 N was applied to each palatal side of the first upper molars and force of 7N was applied to each palatal side of the first premolars and first upper molars respectively. The use of an actual appliance would have been more accurate.

Maxillary expansion in CLCP patients is usually carried out only in mixed dentition,ie, at a time point when individual morphology greatly varies depending on the skeletal age of the patient. In order to eliminate this age-dependent variability as a distorting factor in the simulations, all measurements were carried out in the present study on a simulation model of a 20-year-old adult, because the variability of the anatomical structures is smaller at this age than it is during the mixed dentition phase. The systematic error arising from this, however, must be considered when interpreting the results.

Future simulation studies should endeavor to compute the distribution of expansions for different individual and age-dependent anatomic states.

V. Conclusion

To maximise the treatment mechanics and minimise the iatrogenic damage of using expansion forces on CLCP, this study was conducted to evaluate the effects of SME and RME on various cranial structures and dental structures. Three FEM model of the skull with CLCP extending into alveolus, alveolus and premaxilla, and complete unilateral cleft was created using the Solidworks software and orthodontic force of 2N and 7N to simulate the transversely acting forces of the tooth borne slow expansion device like quad helix and tooth borne rapid expansion device like hyrax appliance

The results of the present study using the three-dimensional FEM of a human skull indicated that the transverse orthopaedic forces not only produced an expansive force at the midpalatal suture but also produce high forces at various structures on the craniofacial complex, particularly the sphenoid and zygomatic bones.
This study also revealed that in the presence of a continuous cleft in the jaw and palate area, slow expansion orthodontic forces (quadhelix) already suffice to bring about a skeletal widening of the maxilla.

In place of the quadhelix appliance, other equipment can also be used to generate moderate transverse forces in cleft patients. Alternatives to the quadhelix apparatus include, for example, the compound palatal arch and the modified maxillary expansion apparatus that only produces moderate forces upon activation of a special nickel-titanium expansion screw. According to the present results, the use of a rapid maxillary expansion appliance with higher forces is not necessary among cleft patients because orthodontic forces of below 5 N already suffice to achieve a skeletal effect in the midface and the cranial base.
The results of our study can be summarized as follows:

1. that in the presence of a continuous cleft in the jaw and palate area, slow expansion orthodontic forces (quadhelix) already suffice to bring about a skeletal widening of the maxilla.
2. As the extent of the cleft increased and the length of the suture decreased the amount of forces required to bring about expansion is less.
3. There was downward and forward movement of the maxilla with a tendency toward posterior rotation.
4. The pterygoid plates were displaced laterally.
5. The distant structures of the craniofacial skeleton (zygomatic bone, temporal bone, and frontal bone) were also affected by the transverse orthopaedic forces.
6. In the frontal plane, the centre of rotation of the maxilla is somewhere approximating the frontonasal suture.
7. The lateral nasal cavity wall was displaced laterally, indicating an increased nasal cavity width.
8. The maximum von Mises stresses were found along the frontomaxillary, nasomaxillary, and frontonasal sutures followed by the zygomaticotemporal and sphenozygomatic sutures.
9. The zygomaticomaxillary, zygomaticotemporal, and zygomaticofrontal sutures were associated with both tensile and compressive stresses.
10. Buccal crown tipping of the posterior teeth takes place.

References

[1]. Sousa AD, Devare S, Ghanshani J. Psychological issues in cleft lip and cleft palate. J Indian Assoc Pediatr Surg. 2009 14(2):55-8.
[2]. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J
[3]. Orthod. 1970;57(3):219-55.
[4]. Corbridge JK, Campbell PM, Taylor R, Ceen RF, Buschang PH. Transverse dentoalveolar changes after slow maxillary expansion. American journal of orthodontics and dentofacial orthopedics. 2011;140(3):317-25.
[5]. Agarwal A, Mathur R. Maxillary Expansion. Int J Clin Pediatr Dent. 2010,3(3):139-46.
[6]. Işeri H, Tekkaya AE, Oztan O, Bilgiç S. Biomechanical effects of rapid maxillary expansion on the craniofacial skeleton, studied by the finite element method. Eur J Orthod. 1998 Aug;20(4):347-56. doi: 10.1093/ejo/20.4.347. PMID: 975381
[7]. Ballanti F, Lione R, Fanucci E, Franchi L, Baccetti T, Cozza P (2009) Immediate and post-retention effects of rapid maxillary expansion investigated by computed tomography in growing patients. Angle Orthod 79:24–29
[8]. Brunetto M, Andriani JSP, Ribeiro GLU, Locks A, Correa M, Correa LR (2013) Three-dimensional assessment of buccal alveolar bone after rapid and slow maxillary expansion: a clinical trial study. Am J Orthod Dentofac Orthop 143:633–644
[9]. Jafari A, Shetty KS, Kumar M. Study of stress distribution and displacement of various craniofacial structures following application of transverse orthopedic forces—a three-dimensional FEM study. Angle Orthod 2003; 73:12-20.
[10]. Holberg C, Holberg N, Schwenzer K, Wichelhaus A, RudzkiJanson I. Biomechanical analysis of maxillary expansion in CLP patients. Angle Orthod 2007; 77:280-7.
[11]. Gautam P, Zhao L, Patel P. Biomechanical response of the maxillofacial skeleton to transpalatal orthopedic force in a unilateral palatal cleft. Angle Orthod 2011; 81:503-9.
[12]. Vasant MR, Menon S, Kannan S. Maxillary Expansion in Cleft Lip and Palate using Quad Helix and Rapid Palatal Expansion Screw. Med J Armed Forces India. 2009;65(2):150-3.
[13]. McNally MR, Spary DJ, Rock WP. A randomized controlled trial comparing the quadhelix and the expansion arch for the correction of crossbite. J Orthod. 2005 ;32(1):29-35
[14]. Chaconas SJ, Caputo AA. Observation of orthopedic force distribution produced by maxillary orthodontic appliances. Am J Orthod. 1982; 82:492–501.
[15]. Derichsweiler H., Die Gaumennahterweiterung. Fortschr- Kieferorthop. 1953; 14:15.
[16]. Hicks EP. Slow maxillary expansion. A clinical study of the skeletal versus dental response to low-magnitude force. *Am J Orthod.* 1978;73(2):121–141.

[17]. . Cassi D, Di Blasio A, Gandolfinini M, Magnifico M, Pellegrino F, Piancino MG. Dentoalveolar effects of early orthodontic treatment in patients with cleft lip and palate. J Craniofac Surg 2017; 28:2021-6.
[18]. Ruel WB. The quad helix appliance. Semin Orthod 1998; 4:231-7.
[19]. Prakash A, Tandur AP, Rai S. Slow expansion in cleft patient with quad helix. Indian J Dent Adv 2012; 4:772-5.
[20]. Bell RA, LaCompte EJ. The effects of maxillary expansion using a quad-helix appliance during the deciduous and mixed dentitions. *Am J Orthod.* 1981; 79:156–161.

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