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Biomechanical Point of View of Craniofacial Growth Associated with Maxillary Cleft

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Abstract: ***Maxillary clefting is a well-recognized condition. It will result in growth retardation and marked aesthetic problem. Repair had been accused to cause abundancy in the scar production that claimed to cause most of the cleft sequalae. We had suggested a new theory that explain growth retardation. Numerical model had been built. Results are clearly showing the disturbed distribution in the loads that stand behind the maxillary hypoplasia***

Keywords: maxillary clefts, numerical simulation, biomechanics, craniofacial growth

1. Introduction

Different clefts in the palate are associated with maxillary hypoplasia [1]. Most of the theories about this are attributing it to the scar tissue resulting from the corrective surgery and the scarcity of perfusion due to poor vascularity [2].

We hereby suggest a theory by which we attribute this hypoplasia to defective transmission of stress between both sides, yet the role of facial muscle on the development needed to be investigated deeply. This theory seems to surpass meaning the current theories in mechanical point of view [3].

Although cleft repair surgery compromises vascularity and produces a significant amount of fibrosis that will constitute a continuous tethering and shrinkage force to hinder the growth, the absence of reciprocation of loads should be investigated. In our paper about endochondral ossification, we had demonstrated the importance of this reciprocation.

When a load is exerted on one side of the maxilla, there will be deflection of that side that is also transmitted to the other side via the hard palate [4]. Application of a force on a bony domain will result in almost always elastic deformation within the scope of what we could consider a static change. The chewing could be regarded as a static linear event. The mechanical loading of the bones produces a certain deformation that the cells should face to behave the designated needed changes [5].

In most instances, cellular activity of the bone is derived by the linear strain, while chemical driving forces are derived by the plastic changes where bone matrix had been exposed to higher strains [6]. Bone has many components that behave plastically even within the what seems to be elastic deformation of the bone. With aid of cellular mechanotransduction, bone remodeling continues to improve the bone structure and repair any possible occurred damage or microcrack [7]. Bone should be having slightly strength than the actual need and should remain within this range.

Mechanical deformations are not haphazardly distributed but are very controlled processes. Any bony domain has its cellular component connected to each other and genetically oriented that is capable to adapt it to the loads faced. This genetic map had settled the shape of the bone during the growth phase [8] and continue to preserve its structural integrity. Bone had self-optimizing capacity. Transfer of bone segment to another place will result in osteolysis and possible total resorption due to the difference in the loading conditions. This is well known sequel in bone grafting surgery. These core ideas must be held in the context of reviewing bone changes associated with any abnormality whether iatrogenic or inherited.

Our cleft model will show a digital representation of.

- How forces transmitted from one side to another.
- Importance of the maxillary sinus, we should correlate teeth eruption with maxillary sinus cavity expansion with growth period. These chronological events should not be studied in separation or approached in silo thinking.
- We should indicate the region with the highest strain energy density as these are the regions where bone is getting the needed increase in size.
- Transmission of stresses to the base of the skull will and should be observed.
- The effect of absence of the nasal septum on the growth should be studied. in many cleft cases it had attachment with one side

2. Methods

Our model is based upon our maxillary universal model with modification to fabricate cleft region. It is important to characterize the soft tissues that are established after cleft palate repair, as their simulation is important.

The region of the cleft had been with softer materials that represent the scar tissues. Strain energy density had been used as an indicator for bone remodeling. Any deviation of the distribution of the stain energy density should be reviewed in the context of the clinical presentation of the clefting.

3. Results and discussion

In our model, we had represented the cleft that comprise the hard palate, although the cleft palate if repaired anteriorly only should be also reviewed in separate work. The hard palate as well as the craniofacial region had very complex configuration. Inhomogeneity of the mechanical properties of the craniofacial region, where many tissues had different orientation or orthotropicity and different shapes and size with very complex interfaces, making the numerical simulation very difficult and need careful scrutinizing to make a correct simplification and retrieve sound analysis [9]. Correlation between different growth stages and analysis of each stage, if possible, will yield the part of the needed conclusions.

Our assumption of intramembranous and endochondral ossification gives an insight to the craniofacial growth including cleft cases. Cleft whether in the bone or in the soft tissues will affect stiffness. *Stiffness is one of the prime affecters of the growth whether on the soft or hard tissues level [10].*

Although we had not included it in his paper, the modal analysis showed lower ***Eigenfrequencies*** in comparison to the original normal model with continuous palate. All the maximum displacement after loading the model had been occurred at the soft tissues interface. We had divided the palate into asymmetric two parts and the effect of the nasal septum had been neglected in the current work but would be included in the next works.

No strain energy had been extended to the contralateral side, in the cleft model, depriving the maxilla from the most important growth stimulator in addition to the relatively poor stresses transfer and absence of the reciprocal mechanical stimulation [11].

It is worth mentioning that we had 2 palatal parts, small and large. The force on the large one yield different results from that with force on the small one, especially in the distant sites, ea. floor of the orbit. The force on the anterior regions had a totally different response from that is resulted the more posterior regions. The current simulation is an excellent approach to understand the possible effect of the cleft upon the growth of the whole facial skeleton including remote regions from the defective palate, such as the orbit.

One of the modestly important causes for anterior teeth periodontitis, as we suppose, is the overload and low bone support. The high relative movement between the 2 segments could be the prime cause for the unsuccessful grafting process that is done by many surgeons as well as the poor survival rate for the teeth close to this region [12].

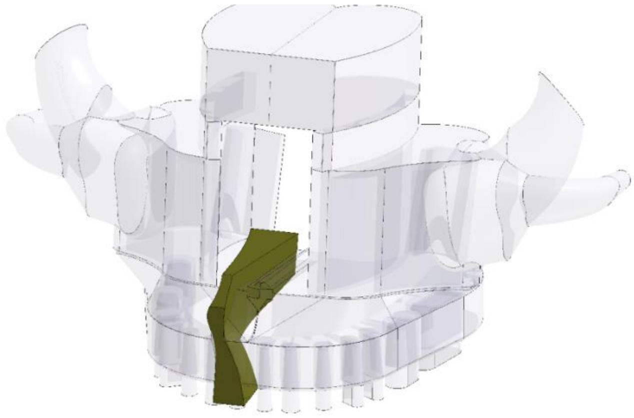

Figure 1: The tissue that represent the scar tissue of repair had been represented as the green region.

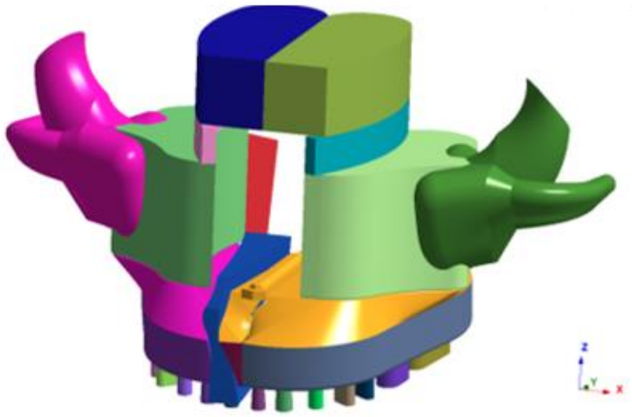

Figure 2: Different bone could be isolated to retrieve all the evaluation criteria.

The blue model is the fibrous tissue that represents the tissue between the 2 maxillary halves on the left and the right. The scar of cleft repair will have some sort of shrinkage that will exert continuous force that will further disturb the normal growth [13]. The scar is an inevitable result of the cleft surgeries. We admit that our model is in need for more tuning to better simulate the real models, but it gives an invaluable insight about the possibly real cause of maxillary restricted growth and hypoplasia [14].

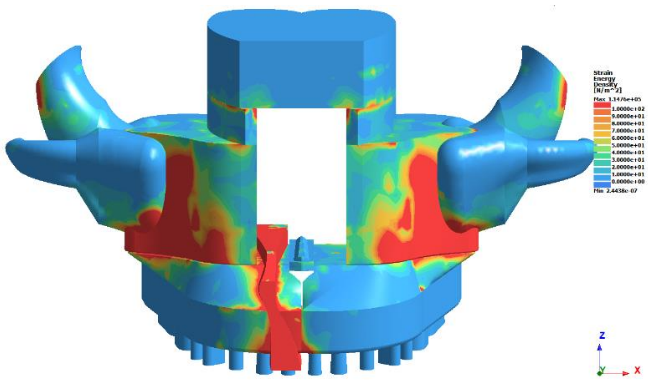

Figure 3: This model represents the scar maturation shrinkage.

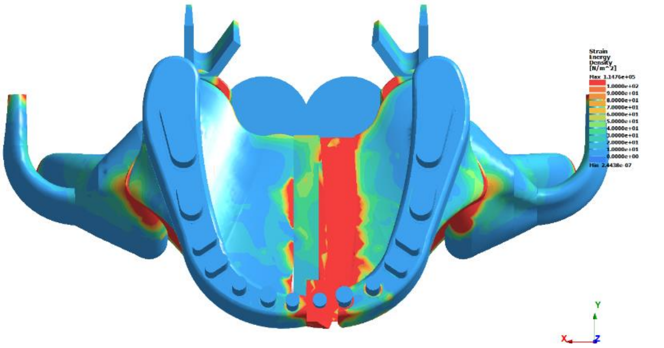

Figure 4: Another view of scar maturity. This will involve remote sites.

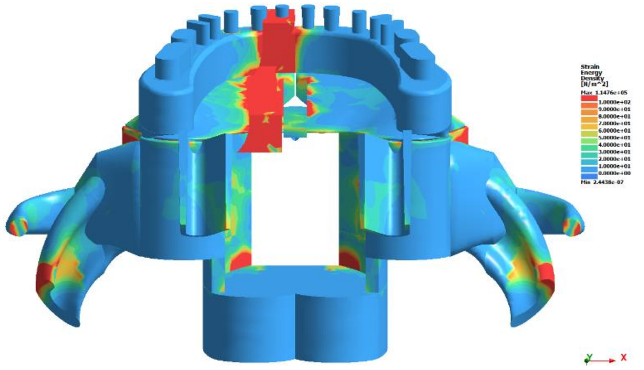

Figure 5: Scar maturation in the individuals where they have soft bone in growing age will have more drastic effects.

Most of the studied models concentrate upon the static changes rather than addressing the dynamicity in the response [15]. In fact, our model had implement the most important factor in the growth, which is loads.

As a reference this is the model of normal maxilla with vertical load on the anterior teeth.

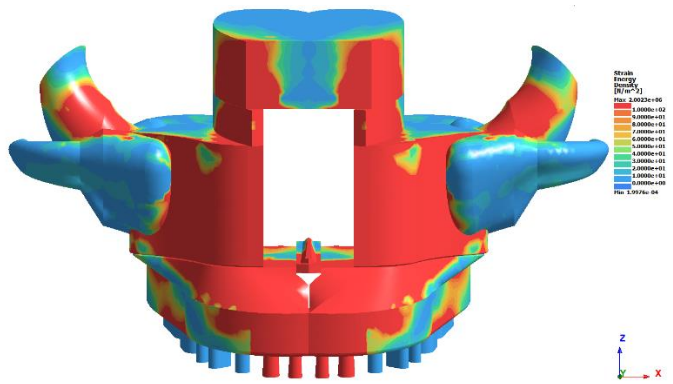

Figure 6: Anterior view of anterior teeth loading.

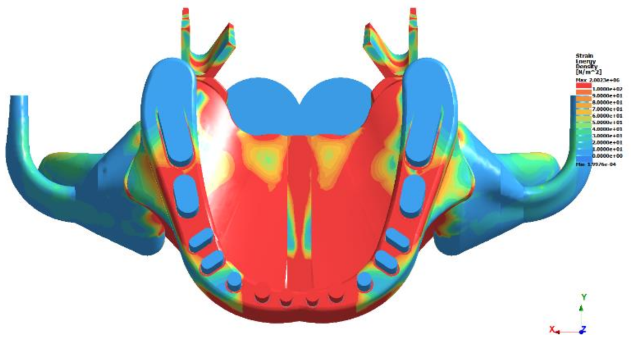

Figure 7: Lower view of anterior teeth loading.

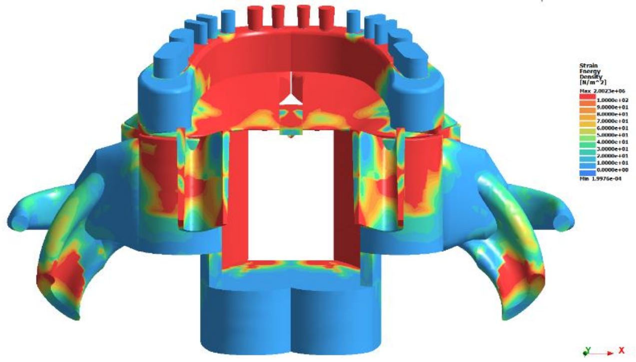

Figure 8: Posterior view of anterior teeth loading.

Previous models are the models of vertical force on the anterior teeth of the maxilla. We admit that it need modification of the legend range to better represent the results.

Next are the vertical force on the anterior teeth model of the cleft model. In the next model we had to consider the scar as a non-shrink model. The anterior teeth are already compromised which could prevent function in critical age from being present which is very important to ensure normal growth.

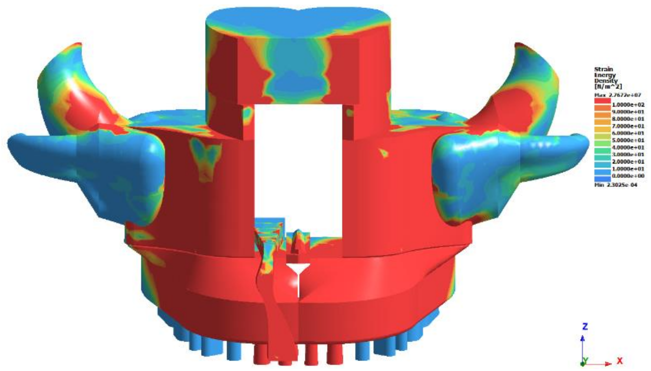

Figure 9: Loading of the anterior teeth involving teeth on both side of the current cleft.

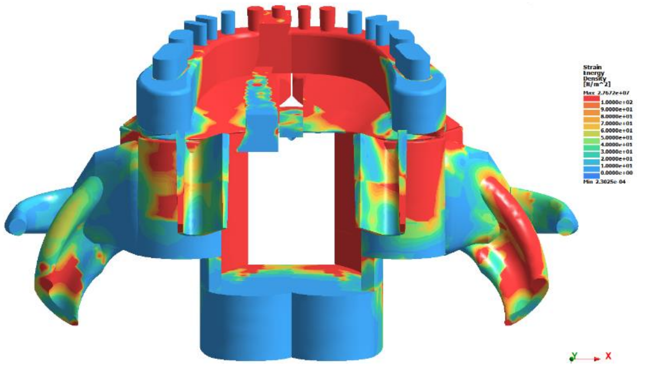

Figure 10: Some region had been deprived from part of the energy density.

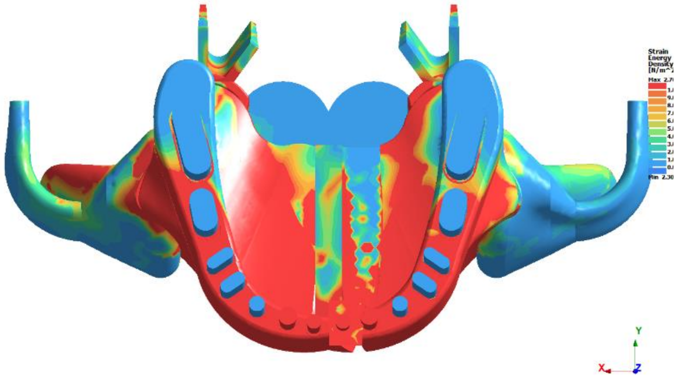

Figure 11 Transfer of the energy to the more posterior regions are limited

Previous are the vertical force on the anterior teeth model of the cleft model. The displacement in the X, Y and Z field should be sought and sought to further characterize the defect deeply.
Next are vertical forces on the posterior teeth of the maxilla.

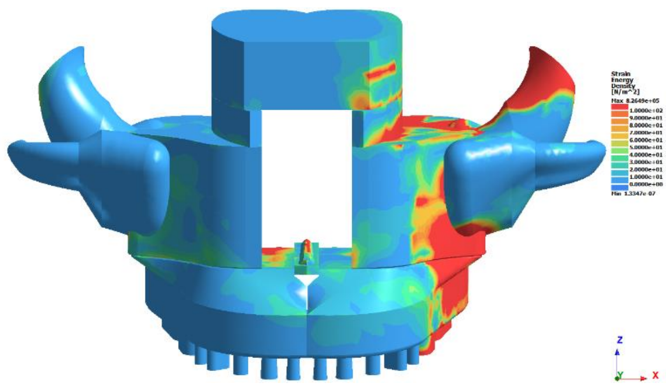

Figure 12 The force application over the posterior teeth had the same effect whether on the left or on the right as the model is perfectly symmetrical.

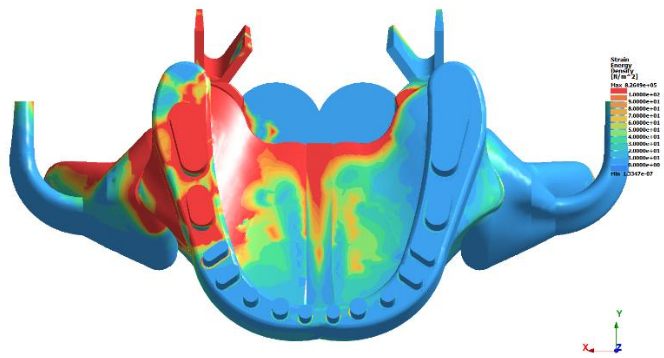

Figure 13 the transfer of the load to other side is apparent in the clef palate model.

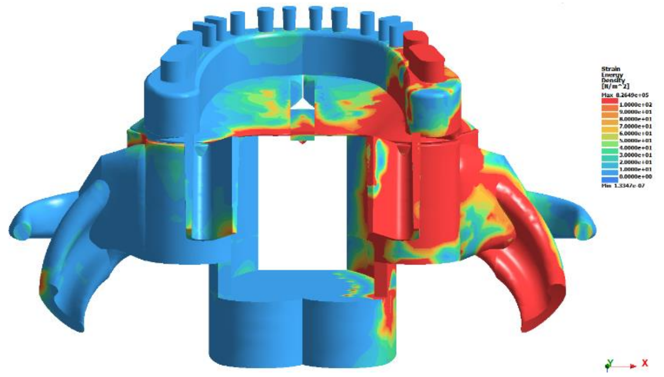

Figure 14 Although there is little transmission of the energy is seen on the contralateral side the absence of this transfer to the other side in the cleft model is apparent

Previous models are vertical forces on the posterior teeth of the maxilla.

Next models are the cleft model with force on the posterior teeth model of the large segment.

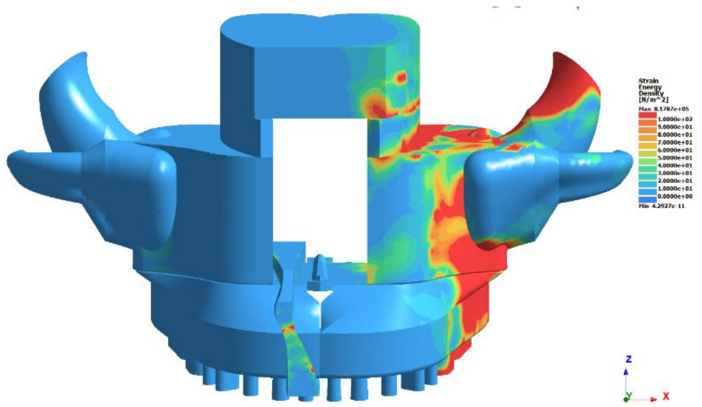

Figure 15The absence of the other side involvement is apparent in comparison to the continuous plate

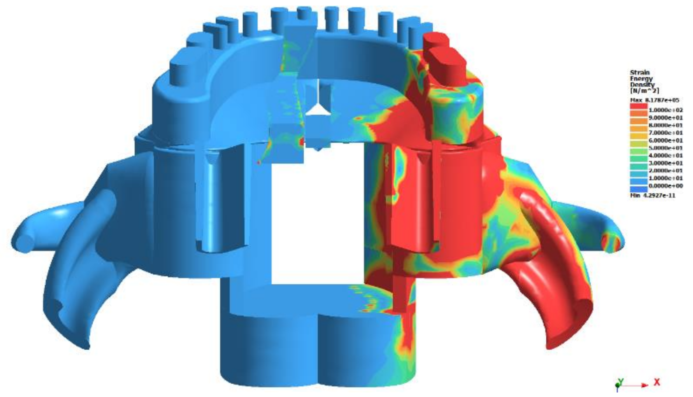

Figure 16 extension to the stresses to the base of the skull is evident from this view

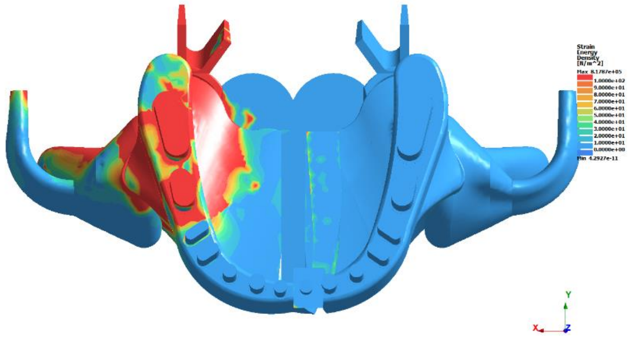

Figure 17: The role of the palate in transferring the loads are evident

Previous models are the cleft model with force on the posterior teeth model of the large segment.

Next model is the cleft model with vertical force on the posterior teeth of the smaller segment.

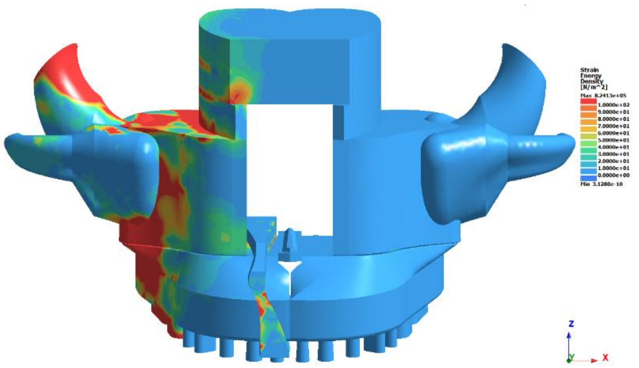

Figure 18: Although the force whether applied on the large or small segment will be anticipated to give poor results due to the cleft presence, we want to apply the force on the smaller maxillary segment

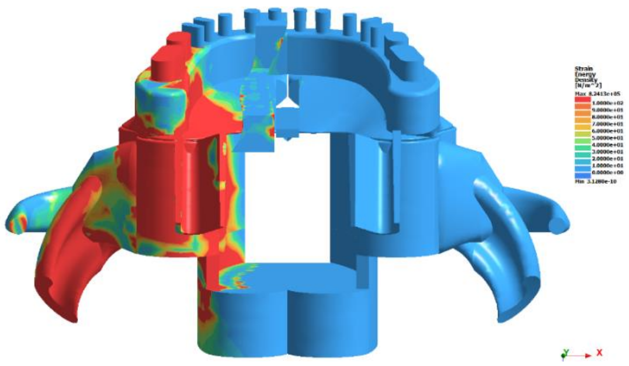

Figure 19: The same defective pattern had been repeated

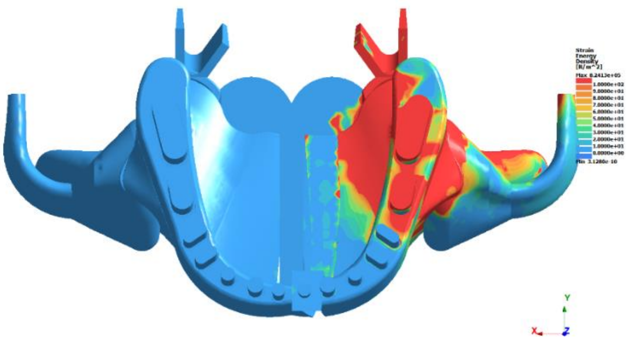

Figure 20: The defective pattern had been also repeated

The previous model is the cleft model with vertical force on the posterior teeth of the smaller segment.

In reality we think that the anterior region will receive less loads in the clef patient in comparison to the same region in the healthy persons. This will result in altered reciprocal stimulation. Next model is the loading of the anterior teeth with less force on the anterior teeth.

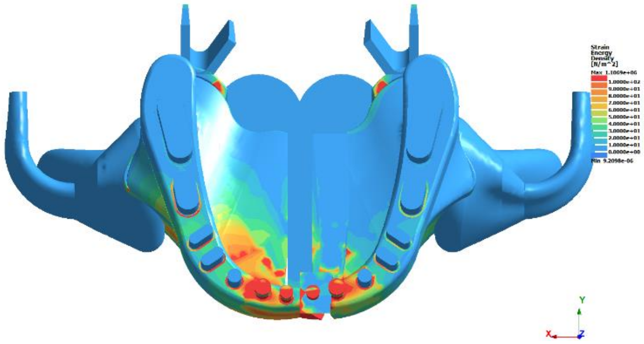

Figure 21: The manipulation of the boundary condition reveal many hidden aspects

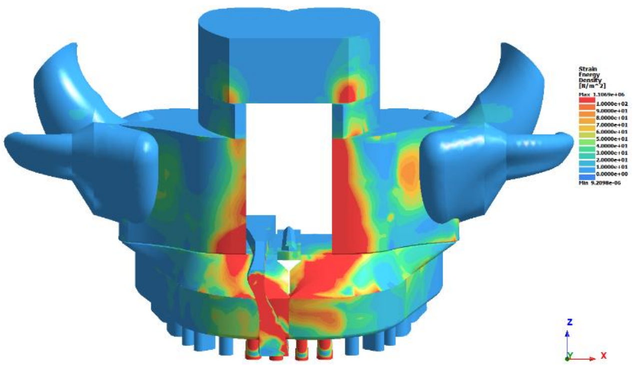

Figure 22: Although we had not done the same force on the normal model, but the disturbed distribution of the loads are clear

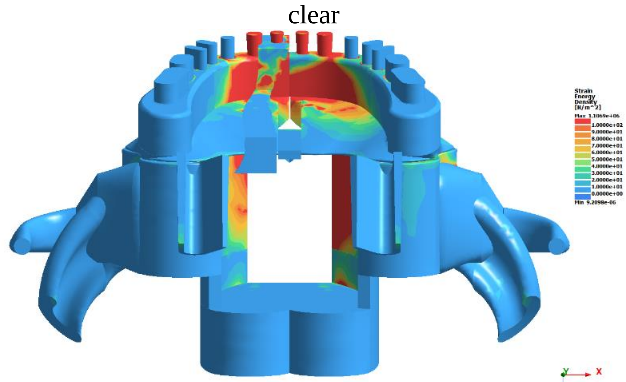

Figure 23: This view give an important aspect of the performance as the pterygoid plates transfer the load to the base of skull in an important fashion

The previous model is the loading of the anterior teeth with less force on the anterior teeth. Disturbance of the strain energy density distribution on the mature bone is well established, but in the growing model it should gain special attention. This is important to know which part will cause halting of the growth, directly of the region with higher strain energy density or indirectly on the other regions.

References

[1] G. P. K. S. G. R. G. T. S. H. Vyas T, "Cleft of lip and palate: A review.," *J Family Med Prim Care.*, 2020.

[2] P. K. M. M. P. Mathew, "Cleft Maxillary Hypoplasia.," in *Oral and Maxillofacial Surgery for the Clinician.*, Springer, Singapore., (2021). .

[3] M. K. Y. Y. Hiroshi Iwasaki, "Does Congenital Cleft Palate Intrinsically Influence Craniofacial Morphology?: Craniofacial Features in Unoperated Submucous Cleft Palate Children in Prepuberty,," *Journal of Oral and Maxillofacial Surgery,*.

[4] P. Nalabothu, C. Verna, B. Benitez, M. Dalstra and A. Mueller, " Load Transfer during Magnetic Mucoperiosteal Distraction in Newborns with Complete Unilateral and Bilateral Orofacial Clefts: A Three-Dimensional Finite Element Analysis.," *Appl. Sci.* , 2020.

[5] B. J. B. S. B. Y. D. J. G. S. K. J. R. J. R. S. Bergmann P, "Loading and skeletal development and maintenance.," *J Osteoporos.* , 2010.

[6] S. R. G. M. H. U. Abel RL, "Clinical Importance of Bone Matrix Damage Mechanisms for Fracture Prevention.," *Curr Osteoporos Rep.* , 2021.

[7] R. K. H. K. Knapik JJ, "Stress Fractures: Etiology, Epidemiology, Diagnosis, Treatment, and Prevention.," *J Spec Oper Med.* , 2017.

[8] R. D. A.-B. C. Adams DJ, "Genetics of aging bone.," *Mamm Genome.* , 2016.

[9] A. &. K. M. Murillo-Rincon, "Insights Into the Complexity of Craniofacial Development From a Cellular Perspective.," *Frontiers in Cell and Developmental Biology.*, (2020). .

[10] R. W. Standerwick RG, "The aponeurotic tension model of craniofacial growth in man.," *Open Dent J.* , 2009.

[11] K. I. K. B. Jang IG, "Analogy of strain energy density based bone-remodeling algorithm and structural topology optimization.," *J Biomech Eng.* , 2009.

[12] E. Dogan, " Comparison of Congenital Tooth Deficiencies Seen in Permanent Teeth in Individuals with Unilateral Cleft Lip and Palate to Those without Cleft Lip and Palate.," *Open Journal of Stomatology.*, (2021)..

[13] D. A. T. L. B. D. Nocini PF, "Treatment of scars with Er:YAG laser in patients with cleft lip: a preliminary report.," *Cleft Palate Craniofac J.*, 2003.

[14] A.-E. AH., " Simulation-based medical teaching and learning.," *J Family Community Med.*, 2010.

Author Profile

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