Journal of
Craniomaxillofacial Research

Vol. 4, No. 1 Winter 2017

Tooth eruption: a "neuromuscular theory". part one

Adolphus Odogun Loto [1*]

1. Department of Restorative Dentistry Faculty of Dentistry Lagos State University College of Medicine Ikeja, Lagos, Nigeria.

ARTICLE INFO

Article Type:
Original Article

Received: 3 Oct 2016
Revised: 2 Nov 2016
Accepted: 29 Des 2016

**Corresponding author:*
Adolphus Odogun Loto

Department of Restorative Dentistry Faculty of Dentistry Lagos State University College of Medicine Ikeja, Lagos, Nigeria.

Tel: +2348121557319
Fax: +2348121557319
Email: dollyloto@outlook.com

ABSTRACT

Objective: Tooth eruption has been a subject of extensive scientific studies; and literature is replete with different mechanisms of migration of a tooth from its bony crypt into the oral cavity. However, there is no common ground on the nature and source of the propelling force among the proponents of these theories. The purpose of this study was to explore the possibility of unifying the currently accepted mechanisms of tooth eruption under single theory.

Materials and Methods: A detailed and systematic analysis, synthesis and integration of the findings from relevant scientific studies on mechanisms of tooth eruption were conducted using search engines such as Medline and PubMed. During the search, phrases such as "tooth eruption", "tooth eruption theories", "tooth eruption and neuromuscular system", "mechanosensation and mechanotransduction" were used. Scholarly published articles on tooth eruption process from 1940 to 2015 were selected based on specific inclusion and exclusion criteria.

Results: The findings from these relevant scientific studies clearly showed a common factor – a propelling force during the different phases of tooth eruption. This propelling force has been explained in terms of piezoelectricity, mechanosensation, mechanotransduction, biomechanical, biochemical, cellular, molecular and enzymic activities involving the jaws and other facial bones during eruption of the developing tooth.

Conclusion: "Neuromuscular theory of tooth eruption" or "unification theory of tooth eruption" is based on neuromuscular forces, arising from muscular contractions in the orofacial region. These neuromuscular forces are being proposed as the origin of the propelling force during the different phases of tooth eruption process.

Key words: Mechanosensation, Mechanotransduction, Neuromuscular, Theory, Tooth eruption.

Introduction

Tooth eruption is the migration or movement of a tooth through its bony crypt and oral mucosa until its emergence into the oral cavity where it establishes its final position at the occlusal plane [1-6]. The initiation, formation, growth, development and eruption of teeth are sequentially arranged as part of general development of the organism [1-7]. However, tooth growth, development and eruption constitute an independent process but it can be influenced by general factors such as nutrition, hormones, trauma etc. [8-12]. The size, shape, number, timing of formation, growth, development and eruption of teeth are genetically determined but environmental factors play an important role in the eruption process and final positions of teeth in oral cavity [13,14]. It should be noted that all the known theories or hypotheses of tooth eruption (vascular pressure and blood vessel thrust, pulpal pressure and pulpal growth, traction by periodontal fibroblast, root elongation, alveolar bone remodeling, formation and renewal of periodontal membrane agree on one point that a force is responsible for the migration of a tooth from its bony crypt into functional occlusion in the oral cavity [1-7].

However, the proponents of these theories differ in the source and mechanism of the eruptive force. Another established fact about tooth eruption is the polarization of the process of bone resorption and bone formation on the coronal part and apical region respectively [15-18]. It is also well established, through animal experimental studies, that cellular, molecular and enzymic activities, within and around the dental follicle and enamel organ of the erupting tooth, are increased as exemplified by the increases in the inter-leukin as well as cells such as osteoclasts, osteoblasts and monocytes [19-35]. The localized molecular, cellular and enzymic processes and changes around the developing and erupting teeth are considered as parts of the genetically pre-determined sequence of events in the process of initiation, formation, growth, development and eruption of teeth [19-35]. The activities of these molecules, cells and enzymes are geared towards preparation of the tooth bony crypt for eruption as well as sustaining the eruption process until functional occlusion is established [1-7].

A combined consideration of all these theories can throw more light into the understanding of tooth eruption but none of these theories can individually explain tooth eruption process because of many unanswered questions and challenges that are associated with all the known theories of tooth eruption e.g. post-eruptive movements of teeth, eruption of rootless tooth, occlusal migration of retained root, eruption of surgically implanted replica of a tooth which had been removed without disturbing its follicle, mesial drift, supra-eruption of a tooth without an antagonist, continuous eruption of rodent's incisors etc. [1-7]. The purpose of this "neuromuscular theory of tooth eruption" is to explore the possibility of unifying all the well-known and accepted theories of tooth eruption under single theory that can adequately explain the origin of the force behind tooth eruption process as well as answering the challenging questions of the current theories of tooth eruption. In this context the part one of this review article is concerned with a brief summary of the currently accepted theories (mechanisms) of tooth eruption, a clear definition and explanation of the proposed neuromuscular theory of tooth eruption, methodology of the review process and the thinking behind the proposed theory.

Summary Of Causes Of Tooth Eruption (Theories)

2.1 Growth and Root formation: This undoubtedly causes an overall increase in the length of the tooth. This increase must be accommodated by the growth of the root into the bone of the jaw, by an increase in jaw height or by the occlusal movement of the crown. The root growth theory presumes that the proliferating root encounters a fixed structure; and the apically directed force is converted into a reactive occlusal force that causes coronal movement of the erupting tooth. Some facts disproving this statement include the fact that rootless teeth erupt, that some teeth erupt to a greater distance than the total length of their roots; and the teeth still will erupt after the completion of root formation or when the tissue forming the root are removed surgically.

2.2 Vascular Pressure and blood vessel thrust. It is based on a known fact that the teeth move in their sockets in synchrony with the arterial pulse. So, local volume changes can produce limited tooth movement. The vascular pressure and blood vessel thrust theory suggest that a local increase in tissue fluid pressure in the periapical region is sufficient to move the tooth [1].

2.3 Bone Remodeling (Apposition and Resorption of bone). This is based on the evidence of bone resorption at the coronal aspect of an erupting tooth while bone apposition takes place at the apical region of the erupting tooth. The dental follicle has been found to be the source for new bone-forming cells and the osteoclasts that are essential for bone remodeling.

2.4 Periodontal Ligament Traction. This based on the assumption that PDL-Dental follicle complex possesses eruptive force because of the traction power that fibroblasts have and because of the experimental results using the continuously erupting rat incisor.

2.5 Control of Endocrine Glands. The growth hormones are essential for growth and development of the organs, tissues and cells of the human body.

2.6 Pressure from muscular action: This is a major factor in eruption process as exemplified by delay or outright failure of tooth eruption owing to neuromuscular disorders and myopathies such as muscular hypotonia.

2.7 Effect of Nutrition cannot be overemphasized in the growth and development of the cells, tissues, organs and systems of the human body. Deficiencies of nutrition have been associated with stunted growth and numerous local and systemic diseases.

2.8 Inherent tendency of teeth to erupt. Teeth are genetically primed to form, grow, develop and erupt in a sequential order.

The Hypothesis

3.1 Definition

The "neuromuscular theory" of tooth eruption states that the coordinated forces of the orofacial muscles, under the influence of the central nervous system, are responsible for the pre-eruptive, eruptive and post-eruptive movements of a tooth with limited growth; and that a time-space dependent, genetically coded and sequentially controlled cellular, enzymic and molecular events (within and around the dental follicle and enamel organ of the developing tooth) would have prepared a pathway for coronal movement of the tooth under the control of the coordinated neuromuscular forces, at the different stages of eruption, until functional occlusion is established.

3.2 The basic assumptions of this theory:

The basic assumptions of this theory are:

3.2.1. The timing, sequence, initiation, formation, growth and development of teeth as well as molecular and cellular activities during eruption phases are genetically controlled [1-7].

3.2.2. The coordinated neuromuscular forces of the orofacial muscles, while stimulating alveolar and basal bones' growth, are responsible for pre-eruptive, eruptive and post-eruptive movements of teeth [8-17].

3.2.3. The coordinated neuromuscular forces are converted into electrical, electrochemical and biomechanical energies for the stimulation of cellular and molecular activities within and around the dental follicle and enamel organ to prepare a pathway as well as other cellular functions for eruption of a developing tooth [18-35].

3.2.4. These forces seem to be active throughout life time. However, they are post-eruptively opposed by antagonistic tooth reactive forces [7,36].

3.2.5. Eruption speed tends to be associated with the degree of muscular activity [7,36].

3.2.6. Period of rapid growth and development of the jaws has been associated with period of rapid growth of orofacial muscles and tooth eruption [7,36].

3.2.7. The trajectory of the depressor and elevator muscles' resultant forces is always directed towards the occlusal plane i.e. occlusally orientated in the absence of other disorientating factors [7,36].

3.2.8. The internally or externally generated neuromuscular forces can answer the questions of post-eruptive movements of teeth, eruption of rootless tooth, eruption of implanted plastic replica of surgically removed developing tooth germ without disturbing its surrounding follicle, continuously growing of rodents incisors and guinea pig molars as well as occlusal movement of retained roots of fractured teeth [36-46].

Methodology

4.1 Literature search

A search of literature on tooth eruption was conducted using search engines such as Google Scholar, Medline, PubMed, and Index Medicus. During the search, phrases such as "tooth eruption", "tooth eruption failure", "general factors affecting tooth eruption", "tooth eruption theories", "Tooth eruption and bone modelling", "tooth eruption and neuromuscular system", "tooth eruption and genetics", "tooth eruption and environment", "tooth eruption and periodontal ligament", "mechanosensation and mechanotransduction" were used. Scholarly published articles on tooth eruption process from 1940 to 2015 were selected based on specific inclusion criteria.

4.1.1. The inclusion criteria include:

(i) Peer-reviewed original and systematic review articles; (ii) Peer-reviewed journals; (iii) Full manuscripts on eruptive process with particular attention on eruption mechanisms, motive force behind eruption, molecular, cellular, enzymic, environmental and genetic factors, theoretical explanation of eruption events, roles of neuromuscular system and periodontal ligament in normal and abnormal eruption processes;

(iv) Studies conducted on humans, other primates and animals; (v) studies conducted anywhere in the world; (vi) studies in children and adults; and (vii) articles written in english language.

4.1.2. The exclusion criteria include:

(i) Non-systematic reviews, abstracts, unpublished data, case report, and commentaries; (ii) non-English manuscripts; and (iii) studies which do not give theoretical explanation on mechanisms of tooth eruption.

One hundred and nineteen articles were selected based on the aforementioned inclusion and exclusion criteria. The findings from these studies were subjected to critical analysis, synthesis and integration for the purpose of establishing a common origin of the motive force behind tooth eruption.

The Thinking Behind The Theory

The thinking, concerning this proposed theory, is based on the established roles of neuromuscular system in the growth and development of the jaw bones, other facial bones as well as tooth eruption. This concept of "neuromuscular theory" is an attempt to unify all older theories of tooth eruption (vascular pressure and blood vessel thrust, pulpal pressure and pulpal growth, traction by periodontal fibroblast, root elongation, alveolar bone remodeling, formation and renewal of periodontal membrane, cellular, molecular and enzymic activities) into single theory that can utilize neuromuscular forces to explain all types of eruptive movements, either normal or pathological in nature. To this end, the author of the proposed theory attempts to link the variously proposed motive forces, behind eruptive movements of teeth, to a common force arising from the neuromuscular system. These neuromuscular forces should be able to answer some challenging and unanswered questions relating to older tooth eruption mechanisms to wit:

(i) the three dimensional space movement of the teeth during the pre-eruptive phase of tooth eruption [7,36-46]; (ii) post-eruptive movements of teeth owing to attrition and defects in the dental rows [7,36-46]; (iii) eruption of rootless tooth [7,36-46]; (iv) continuous eruption of incisors of rodents and molars of guinea pigs respectively [7,36-46]; (v) eruption of surgically implanted replica of a developing tooth germ without disturbance of its dental follicle [7,36-36]; (vi) association of rapid growth and development of jaws in response to tooth formation, tooth growth and development and tooth eruption [7,36-46]; and (vii) delayed tooth eruption associated with myopathies, neuromuscular disorders, metabolic and endocrine disorders and congenital TMJ ankylosis [8-14].

Conclusion

The proposed 'neuromuscular theory of tooth eruption' is based on the coordinated forces of the orofacial muscles under the influence of the central nervous system. This is thought to be achieved through preparation of the pathway for eruption of a tooth-a process which is genetically predetermined and controlled by cellular, molecular and enzymic activities within and around the dental follicle and enamel organ. The establishment of eruption pathway is for the purpose of enhancing the efficiency and effectiveness of the pulling action of the neuromuscular forces during occlusal migration of the concerned tooth. The sustenance of the eruption pathway as well as cellular, molecular and enzymic activities, during the different phases of tooth eruption, is also controlled by neuromuscular forces through conversion of biomechanical forces (muscular forces) into biochemical, chemical and electrical energies.

References

[1] Massler, M., Schour, I. Studies in tooth development: Theories of eruption. Am J Orthod Oral Surg. 1941; 27:552–576.

[2] Marks, S.C., Schroeder, H.E. Tooth eruption: Theories and Facts. The Anatomical Record. 1996; 245:374–393.

[3] Craddock, H.L, Youngson, G.G. Eruptive tooth movement–the current state of knowledge. Br Dent J. 2004; 197:385–391.

[4] Ten Cate, A.R., Nanci, A. Physiologic tooth movement: Eruption and shedding. in: A. Nanci (Ed.) Oral Histology: Development, Structure and Function. 6. Mosby, Toronto 2003:279–280.

[5] Tooth movement. J Dent Res. 2008; 87:414–434.

[6] Sutton, P.R., Graze, H.R. The blood-vessel thrust theory of tooth eruption and migration. Med Hypotheses. 1985; 18:289–295.

[7] Ash, Major M. and Stanley J. Nelson. Wheeler's Dental Anatomy, Physiology, and Occlusion. 9th. Edition 2003. P.38- 41.

[8] Ruta Almonaitiene, Irena Balciuniene, Janina Tutkuviene. Factors influencing permanent teeth eruption. Part one – general factors. Stomatologija, Baltic Dental and Maxillofacial Journal 2010;

12: 67-72,

[9] Garn, S.M., Lewis, A.B., Blizzard, R.M. Endocrine factors in dental development. J. Dent. Res. 1965; 44:243–258.

[10] Psoter, W., Gebrian, B., Prophete, S., Reid, B., Katz, R. Effect of early childhood malnutrition on tooth eruption in Haitian adolescents. Community Dent Oral Epidemiol. 2008; 36:179–189.

[11] Adler, P. Studies on the eruption of the permanent teeth. IV. The effects upon the eruption of the permanent teeth of caries in the deciduous dentition and of urbanization. Acta Genet. 1958; 8:78–91.

[12] Garn, S.M., Lewis, A.B., Kerewsky, R.S. Genetic, nutritional, and maturational correlates of dental development. J Dent Res. 1965; 44:228–242.

[13] Hatton, M.E. Measure of the effects of heredity and environment on eruption of the deciduous teeth. J. Dent. Res. 1955; 34:397–401.

[14] Adler, P. Effect of some environmental factors on sequence of permanent tooth eruption. J. Dent. Res. 1963; 42:605–616.

[15] Epker BN, Frost HM. Correlation of bone resorption and formation with the physical behavior of loaded bone. Journal of Dental Research 1965; 44: 33–44.

[16] Marks, S.C. Jr, Cahill, and D.R. Regional control by the dental follicle of alterations in alveolar bone metabolism during tooth eruption. J Oral Pathol. 1987; 16:164–169.

[17] Wise, G.E., Yao, S., Henk, W.G. Bone formation as a potential motive force of tooth eruption in the rat molar. Clin Anat. 2007; 20:632–639.

[18] Wise, G.E., Lin, F., Marks, S.C. Jr et al, The molecular basis of tooth eruption. in: Davidovitch Z. (Ed.) The Biological Mechanisms of Tooth Eruption, Resorption and Replacement by Implants. EBSCO Media, Birmingham, AL; 1994:383–390.

[19] Wise, G.E., Frazier-Bowers, S., D'Souza, R.N. Cellular, molecular, and genetic determinants of tooth eruption. Crit Rev Oral Biol Med. 2002; 13:323–324.

[20] Sandy C. Marks Jr., Jeffrey P. Gorski and Gary E. Wise. The mechanisms and mediators of tooth eruption – Models for developmental biologists. Int. J. Dev. Biol. 1995; 39:223-230.

[21] Scott, J.M. Development and function of the dental follicle. Brit Dent J. 1948; 85:193–195.

[22] Cahill, D.R., Marks, S.M. Jr. Tooth eruption: Evidence of the central role of the dental follicle. J Oral Pathol. 1980; 9:189–200.

[23] Wise, G.E., Marks, S.C. Jr, Cahill, D.R. Ultrastructural features of the dental follicle associated with formation of the tooth eruption pathway in the dog. J Oral Pathol. 1985; 14:15–26.

[24] Marks, S.C. Jr, Cahill, D.R., Wise, G.E. The cytology of the dental follicle and adjacent alveolar bone during tooth eruption. Am J Anat. 1983; 168:277–289.

[25] Gorski, J.P., Marks, S.C. Jr, Cahill, D.R. et al, Developmental changes in the extracellular matrix of the dental follicle during tooth eruption. Connective Tissue Research. 1988; 18:175–190.

[26] Gorski, J.P., Marks, S.C., Cahill, D.R. et al, Biochemical analysis of the extracellular matrix of the dental follicle at different stages of tooth eruption. in: Davidovitch Z. (Ed.) The Biological Mechanisms of Tooth Eruption and Root Resorption. EBSCO Media, Birmingham, AL; 1988:251–260.

[27] Gorski, J.P., Marks, S.C. Current concepts of the biology of tooth eruption. Crit Rev Oral Biol and Med. 1992; 3:185–206.

[28] Wise, G.E., Frazier-Bowers, S., D'Souza, R.N. Cellular, molecular, and genetic determinants of tooth eruption. Crit Rev Oral Biol Med. 2002; 13:323–334.

[29] Wise, G.E. Cellular and molecular basis of tooth eruption. Orthod Craniofac Res. 2009; 12:67–73.

[30] Hatakeyama, J., Philp, D., Hatakeyama, Y. et al, Amelogenin-mediated regulation of osteoclastogenesis, and periodontal cell proliferation and migration. J Dent Res. 2006; 85:144–149.

[31] Shroff, B., Norris, K., Pileggi, R. Protease activity in the mouse dental follicle during tooth eruption. Arch Oral Biol. 1995; 40:331–335.

[32] Cielinski, M.J., Jolie, M., Wise, G.E. et al, Colony-stimulating factor (CNS-1) is a potent stimulator of tooth eruption in the rat. in: Davidovitch Z. (Ed.) Biological Mechanisms of Tooth Eruption, Resorption and Replacement by Implants. EBSCO Media, Birmingham, AL; 1994:429–436.

[33] Wise, G.E., Lin, F. Regulations and localization of colony stimulating factor-1 mRNA in cultured dental follicle cells. Arch Oral Biol. 1994; 39:621–627.

[34] Wise, G.E., Lin, F., Zhao, L. Transcription and translation of CSF-1 in the dental follicle. J Dent Res. 1995; 74:1551–1557.

[35] Shroff, B., Rothman, J.R., Norris, K. et al, Follic-

ular apoptosis during tooth eruption. in: Davidovitch A., Mah J. (Eds.) Biological Mechanisms of Tooth Eruption, Resorption and Replacement by Implants. EBSCO Media, Birmingham, AL; 1998:71–77.

[36] Logan, W., Kronfeld, R. Development of the human jaws and surrounding structures from birth to the age of fifteen years. J. Am. Dent. Assoc. 1933; 20:379–427.

[37] Cruz DZ, Rodrigues L, Luz JGC. Effects of detachment and repositioning of the medial pterygoid muscle on the growth of the maxilla and mandible of young rats. Acta Cir Bras. 2009 Mar-Apr; 24(2):93-7.

[38] Rodrigues L, Traina AA, Nakamai LF, Luz JGC. Effects of the unilateral removal and dissection of the masseter muscle on the facial growth of young rats. Braz Oral Res. 2009 Jan-Mar; 23 (1):89-95.

[39] Kiliaridis S. Masticatory muscle influence on craniofacial growth. Acta Odontol Scand. 1995 Jun;53(3):196-202.

[40] Sarnat BG, Robinson IB. Experimental changes of the mandible. A serial roentgenographic study. J Craniofac Surg. 2007 Jul; 18(4):917-25.

[41] Whetten LL, Johnston LE Jr. The control of condylar growth: An experimental evaluation of the role of the lateral pterygoid muscle. Am J Orthod. 1985 Sep;88(3):181-9

[42] Fernanda Engelberg Fernandes Gomes, Rogério Bonfante Moraes, João Gualberto C Luz. Effects of temporal muscle detachment and coronoidotomy on facial growth in young rats. Brazilian oral research August 2012; 26(4):348-54·

[43] Miller, AJ, Chierici, G. The bilateral response of the temporal muscle in the rhesus monkey (Macacca mulatta) to detachment of the muscle and increased loading of the mandible. J Dent Res. 1977;56:1620.

[44] Kiliaridis S, Mejersjo C, Thilander B. Muscle function and craniofacial morphology: a clinical study in patients with myotonic dystrophy. Eur J Orthod 1989; 11:131-138.

[45] Kiliaridis S. Masticatory muscle function and craniofacial morphology. Swedish Dental Journal Suppl. 36, 1986.

[46] Kiliaridis S. The importance of masticatory muscle function in dentofacial growth. Seminars in orthodontics 2006; 12(2):110-119.

Please cite this paper as:
Adolphus Odogun L; Tooth eruption: a "neuromuscular theory". part one. J Craniomaxillofac Res 2017; 4(1): 278-283