Tooth Eruption: A Review

Sathya Priya R. [1], Kavitha B.[2], Sivapathasundharam B.[3]

[1]Post Graduate Student, [2]Professor, [3]Professor and Head of the Department, Department of Oral Pathology, Meenakshi Ammal Dental College, Meenakshi Academy of Higher Education and Research, Chennai, India

Abstract

Tooth eruption, is a developmental process which occurs in a 3–dimension, and various factors are considered to play a major role during tooth eruption. Numerous theories are put forward to explain this process in a different perspective. A better elucidation and understanding of this entire process is essential to identify the cause behind any deviations in eruption from the normal and in treating the same.

Keywords: *Tooth eruption, root formation, pulp growth, bone remodelling, Vascular Pressure.*

Introduction

The term, "Eruption" takes its origin from a latin word "Erumpere". The definition of eruption is "the axial (or) occlusal movement of the tooth from its position of development in the jaws to its functional position in the occlusal plane".[1] The phenomenon of tooth eruption is considered to be physiological, the timing of which depends on numerous factors. The initiation of tooth development and its eruption in the appropriate timebecomes essential for the maintenance of a proper and healthy dentition.[2] In the present paper, the initiation of tooth formation, various stages of the tooth development, root formation and sequence of eruption are discussed.

Initiation of tooth development: The initiation of tooth development is thought to be induced by the neural crest cells, which arisefrom the embryonic ectodermal layer.[1] In the tentative position of the jaws, a horse shoe shaped Primary epithelial band forms corresponding to the future dental arches. This gives out two subdivisions– Dental Lamina, from which the tooth bud forms and the Vestibular Lamina from which the vestibule develops.[5] Successional lamina arises lingually from the dental lamina, from which the permanent dentition arises, which are the successors of the deciduous teeth. The dental lamina disappears later but few remnants remain, called as the "Cell rests of Serres".[1] Vestibular lamina is the one which rapidly enlarges and degenerates thereby forming the future vestibule. With initiation, proliferative activity gets intensified at certain points of dental lamina which in turn results in the various stages of tooth development. The formative cells which arises as a result of proliferation is said to give the blueprint for future tooth by morpho differentiation.

Stages: Indicating the morphologic changes, the stages of the tooth development process includes, Bud, Cap, Early and Advanced Bell stages (Fig: 1). In the bud stage, each dental lamina differentiates at 10 different points to give rise to the ovoid or round swellings from the basement membrane, corresponding to the future dental positions. The swellings of the dental lamina resembles to bud microscopically. Since certain cells of the tooth bud form the enamel, it constitutes the enamel organ. Condensed ectomesenchyme subjacent to enamel organ constitutes dental papilla. Dental sac constitutes the condensed ectomesenchyme surrounding the tooth bud and dental papilla.

Cap stage of tooth development forms as a result of proliferation of tooth bud and an invagination in it. The peripheral cuboidal cells form the outer enamel epithelium and in contrast to this, the inner enamel epithelium is composed of tall columnar cells lining the

Corresponding Author:
Dr. Sathya Priya R.
Post Graduate Student, Department of Oral Pathology, Meenakshi Ammal Dental College, Meenakshi Academy of Higher Education and Research, Chennai, India
e-mail: drsivapatham@yahoo.co.in

concavity. In addition to these layers, there are central stellate cells which synthesize and secrete the hydrophilic glycosaminoglycans, and forms a layer called the Stellate Reticulum.[1] Enamel knot is a structure which is formed by the condensation of the central most cells of the enamel organ and studies reveal that, enamel knot acts as a signalling centre, playing essential role in determining tooth shape.[1]

In bell stage, the epithelial cap deepens and resembles the shape of a bell with outer enamel epithelium bordering enamel organ and inner enamel epithelium bordering dental papilla. It is divided into early and advanced bell stage. The point where outer and inner epithelium meets is called the cervical loop. In the cervical loop, cell division continues until crown formation is complete and epithelial component of root arises from here. Stratum intermedium forms between inner enamel epithelium and stellate reticulum.[5] During this stage, ameloblastsarise from inner enamel epithelium, odontoblasts differentiate from dental papilla, forming predentin and dentin layer (dentinogenesis), followed by enamel formation(amelogenesis). This process of deposition of dental hard tissues is referred to as apposition.

Root formation: Once the enamel and dentin reach the future CEJ, the root formation begins. The Hertwigs Epithelial Root Sheath(HERS)(Fig: 2), which plays an essential role in radicular dentin formation and in molding the root shape, forms by the proliferation of cervical loop and encloses the basal portion of the dental pulp. With the odontoblastic differentiation, the root dentin forms following crown dentin. With the formation of radicular dentin the HERS loses it structural continuity and detaches from the root. The remnants of HERS remain as discrete clusters which are referred to as the epithelial cell rests of Malassez.[1]

The root formation is followed by the formation of periodontal ligament and alveolar bone. Periodontal ligament, a highly vascular specialized connective tissue covers the tooth root and is present between cementum and alveolar bone. During the process offormation of Periodontal ligament, the cervical loop of the tooth bud is formed by the proliferation of inner and outer enamel epithelium in a continuous manner. The mesenchymal cells of dental follicle proper and perifollicular mesenchyme are the two different populations of the dental follicle cells. These cells are randomly oriented between the alveolar bone and hertwigs epithelial root sheath. Comparing these two populations of cells, the perifollicular mesenchymal cells which have an euchromatic nucleus, very little cytoplasm, rough endoplasmic reticulum with short cisternae, mitochondria, free ribosomes and an inactive golgi area are more widely separated. With the continuation in the root formation process, the cells in the perifollicular area becomes elongated due to gain in polarity. As a result of this, active synthesis and deposition of collagen fibrils and glycoproteins happens. The synthesized collagen fibres get embedded in the cementum. The alveolar bone, a part of maxilla and mandible, forms gradually with development and eruptiom of teeth. This forms and supports the tooth socket and diminishes in height with tooth loss.[1]

Tooth movement: The complex physiological tooth movement starts with the development of tooth and continues even after eruption, hence categorized into pre-eruptive, eruptive and post-eruptive movements. Pre-eruptive tooth movement begins from the time of initiation of tooth formation to the time of initiation of root formation.[5]The tooth movement occurs in association with the growth of the jaws. The pre-eruptive movement places the teeth in a definitive position in the jaw thereby enabling eruptive movement.[5] Pre-eruptive tooth movements occur intraosseously and requires remodelling of the bony crypt wall which happens by the selective deposition and removal of the bone.[6]

The eruptive phase of tooth movement starts from the root formation till the tooth reaches the occlusal plane. The tooth moves from its developmental position to the occlusal level. The principal direction of movement is either axial or occlusal. After the emergence, the tooth crown keeps moving occlusally until it comes in contact with its antagonist in the occlusal plane. During this process, the tooth crown begins to get exposed gradually with an apical shift of the dentogingival junction. For the intraosseous eruptive tooth movements, two things have to happen – the resorption of overlying tissue to provide an eruptive path and a force for the tooth to move vertically. The blood vessels decrease in number and is also accompanied by the degeneration of nerve fibers and the connective tissue overlying the tooth germ. This leads to the formation of an eruption pathway, which appears as an inverted triangular area of altered tissue.[6]

The post eruptive tooth movements happen, once the tooth reaches its functional position in the oral cavity. These tooth movements maintain the position of

the erupted tooth while the jaw continues to grow and compensates for the occlusal and proximal wear. These movements compensate the proximal and occlusal wear and continue throughout the life time.[6] Tooth wear occurs even at the contact points between the teeth. In order to compensate it a proximal drift takes place. Histologically this drift is a selective deposition and resorption of bone on the socket walls by osteoblasts and osteoclasts respectively. Post eruptive tooth movements are divided into 3 categories namely, movements which helps in accommodating the jaw growth, movements which compensate the occlusal wear, to compensate for continued occlusal wear, movements which aids in accommodating the wear of tooth that occurs interproximally.[5]

Eruption: Based on the type of tooth and the time of eruption, human dentition is categorized into Primary (Deciduous) dentition (Fig: 4A), Mixed dentition (Fig: 4B) and Secondary (Permanent) dentition (Fig: 4C). Primary dentition comprises of 20 teeth and erupts between 6 months and 2.5 years. They start exfoliating between 6 years to 11 years. Permanent dentition erupts between 6 – 7 years and 18 – 21 years of age. Since both the primary and permanent dentition is present in the age group between 6 – 12 years, this phase is termed as mixed dentition phase.

Theories: The mechanism which brings about the movement of tooth is still debatable, as it is thought to be a combination of various factors. Various theories have been proposed in order to brief out the process of eruption.[12] The various theories of tooth eruption include:

Root Formation Theory: Formation of root causes an increase in root length and hence this is considered to be the essential cause for tooth eruption, as root growth produces a force sufficient for bone resorption. This concludes that, although a force is produced by root growth, this force cannot be translated into eruptive tooth movement unless there exist some structure that withstands the force at the base of the tooth.[5]However the facts that went on as a drawback was that even rootless teeth was able to erupt. Some teeth erupt to a greater distance than the total root length; and the certain teeth erupt after root formation is completed or when the tissue essential for root formation is removed.[14]

Pulp Growth Theory: As the root formation continues, the thickness of the radicular dentin increases resulting in the decrease in size of pulp cavity. The pulp growth theory states that the growth or constriction of the pulp generates a force which is propulsive in nature by the growth of dentin, pulp and the hydraulic effects happening within the pulpal vasculature. The drawback of this theory is that the eruption happens even in pulpectomized tooth.[6]

Vascular Pressure Theory: Also known as "Blood thrust theory" or "Hydrostatic pressure theory", it is considered to overlap with the pulp growth theory. It is believed that the tooth movement synchronises with the arterial pressure, thereby the local volume changes produce a limited tooth movement. It also states that the eruptive force is provided by the pressure exerted by the blood vessels within the tooth. This is against the fact that pulpless tooth erupt. Also studies state that the removal of root and local vasculature does not impede the eruption of tooth, which again becomes debatable.[14]

Bone Remodelling Theory: This theory tends to play a prime role in tooth movement. Bony remodelling of the jaws has been linked to the tooth eruption, in that, in the pre-eruptive phase of tooth movement, the growth pattern of maxilla or mandible moves the teeth by the process of selective deposition and resorption of bone. Whether the bony remodelling around the teeth causes the teeth to erupt or is the effect of the tooth movement is not clearly known, but both the circumstances apply.[5] Studies also indicate that the control resides within the bone lining cells, the osteoblasts. However it is also stated that a conclusion cannot be drawn out unless there also happens coincidental bone deposition in the base of the crypt, the prevention of which can pose a challenge to the eruption of tooth.[14]

Periodontal Ligament Traction Theory: The formation and renewal of periodontal ligament is considered to be an essential factor in tooth eruption due to the traction power of the fibrobasts. A strong deal of evidence says that the eruptive forces exist in the dental follicle – periodontal ligament complex.[14] Shrinkage of collagen fibers exhibits a force that plays a very important role in tooth eruption. If the tooth has to erupt, there should be a space in the eruption path, a lift or pressure from the apical region and required adaptability in the periodontal ligament.[6] Bone resorption and deposition involved which plays a major role in the movement of the tooth, is considered to be one of the critical surface phenomenon between the soft tissue and the bony interface, which are present surrounding the developing

tooth. Later it is confirmed that the periodontal ligament fibroblast orientation significantly increased during eruption. However, studies state that, the force required for the normal physiological movement of the tooth is not exerted by the fibroblasts. Still, the lack of occlusal movement or mesial drift of ankylosed tooth and implants, which lack the intervening periodontal ligamentis yet to be explained.[14]

Neuromuscular Theory: Also known as the unification theory of tooth eruption it is primarily based on the neuromuscular forces which takes its origin from the contraction if the musculature present in the orofacial region. This theory states that the combined forces exhibited by the orofacial muscles, which primarily are controlled by central nervous system, play an essential role in the active movements of a tooth. This combination of forces are converted into energies of various forms such as electrical, electrochemical and biomechanical energies, which becomes essential for the stimulation of cellular and molecular activities taking place within and around the dental follicle and enamel organ. These changes happens inorder to prepare a pathway as well as to bring out other cellular functions required for a developing tooth to erupt.[15]

Dental Follicle Theory: This theory postulates that the dental follicle has the potency to induce, resorption of bone above the developing crown and bone apposition below it. This in turn brings about an eruptive pathway. [6]Experimental removal of dental follicle results in eruption failure. Various molecular studies reveal that the eruption is regulated by inductive signals between the dental follicle, reduced enamel epithelium, stellate reticulum and alveolar bone. It is also stated that the osteoclastogenesis or the bone resorption is regulated by the coronal aspect of the dental follicle whereas the process of bone formation or osteogenesis is regulated by the basal aspect of the dental follicle.[14]

Molecular Events in Tooth Eruption: The eruption of tooth is considered as a programmed and localized event. Various factors essential for tooth eruption are EGF, TGF, CSF, c-fos, NFκB, MCP, VEGF, RANKL, OPG etc. Determination of the molecules essential for tooth eruption, started with the isolation of Epidermal Growth Factor(EGF). EGF injection into the rodents accelerated the eruption of incisors. In rats both EGF and Epidermal Growth Factor Receptor (EGFR), immunolocalize to the dental follicle(DF), and get expressed in the early postnatal period.[8]

Transforming Growth Factor - α(TGF-α), has shown to accelerate the incisor eruption in mice. Rodents lacking TGF-α also erupt on schedule, showing that EGF alone can initiate the process. Osteopetrotic rodents usually have unerupted teeth and lack functional Colony Stimulating Factor-1(CSF-1). In such cases, injection of CSF-1 restores the process. This is because CSF-1 brings about and increase in the TRAP-positive mononuclear cells count, present in the dental follicle along with increase in the number of osteoclasts in the alveolar bone. Other genes which potentially enhance eruption are transcription factor genes c-fos and Nuclear factor kappa B(NFκB). c-fos is required for the process of fusion of mononuclear cells and osteoclasts and the role of NFκB is osteoclastic differentiation.[9]

Studies using RT-PCR showed that CSF-1 and MCP-1(Monocyte Chemotactic Protein-1) are expressed maximally in the dental follicles at day 3, and are usually chemotactic for the mononuclear cells.[10]CSF-1 is necessary for the osteoclast formation from monocytes. MCP-1 is considered to be the well-known chemokine for monocytes.[9] For eruption to occur, the mononuclear cells must fuse to form osteoclasts, for creating an eruption pathway byosteoclastogenesis. The essential molecules which promotes this are CSF-1 and Receptor Activator of Nuclear Factor-kappa B Ligand (RANKL), whereas osteoprotegrin (OPG), inhibits this. Vascular Endothelial Growth Factor (VEGF) has the ability to replace CSF-1 and upregulate the RANK expression on the osteoclast precursors.[10]

RANKL, a membrane bound protein, and a member belonging to the TNF (Tumor Necrosis Factor) ligand family, induce the formation and activation of from its precursor. OPG, found to prevent the differentiation of osteoclasts, also acts as a receptor for RANKL.[10]The expression of RANKL is upregulated by the by TNF-α, IL-1α and TGF-β. The OPG expression is enhanced by BMP-2(Bone Morphogenetic Protein-2), which enhances OPG secretion from dental follicle cells.[11] Currently, intense research has begun for transcription factors, the "master regulators" of osteoblastic differentiation. One such factor is Osf2(Osteoblast Specific Transcription Factor 2).[9]

Factors affecting tooth eruption: Various factors influence the tooth eruption and become a part of the disturbances occurring in it. The important local factors influencing tooth eruption are: Supernumerary teeth(Fig:3A), crowding(Fig:3B), arch length deficiency,

odontogenic cysts and tumors, dentigerous cysts, enamel pearls(Fig:3F), gingival hyperplasia (Fig:3D), premature loss of primary tooth, ankylosis (Fig:3E), thumb sucking, tongue thrusting (Fig:3C), eruption cysts, eruption sequestra and fibrous developmental malformations.[20]

Genetic factors play a prime role. Certain genetic disorders affect tooth eruption either by delaying or by a complete failure of tooth eruption.[3] Gender also plays an essential role with the permanent teeth erupting earlier in girls which is mainly due to the earlier onset of maturation.[3] Though very few studies have emphasized on the nutritional influence, it is proved that chronic malnutrition can lead to delayed eruption. Lack of nutritional supply alters bone mineralization leading to disturbances in bone formation. Eruption of permanent teeth is important as it also stimulates the jaw growth. Experimental evidences also suggest that preterm children have delayed eruption.[16]

Various studies have found that children who belong to the higher socioeconomic status show earlier eruption. [17] Studies also state a positive correlation between the height and weight of the body with teeth emergence, with the taller and heavier children showing an early dental growth.[18] Endocrinal disturbances, which affects the entire body also affects the dentition. The hormonal conditions such as hypothyroidism, hypopituitarism, parathyroidism and pseudohypoparathyroidism usually exhibit delayed permanent teeth eruption. In contrast, turner's syndrome exhibits an accelerated development.[19]

The other systemic conditions influencing tooth eruption includes: Down's Syndrome, Cleidocranialdysostosis, hypothyroidism, hypopituitarism achondroplastic dwarfism, Vitamin D resistant rickets, long term chemotherapy, ichthyosis, oral cleft, renal failure, exposure to hypobaria, radiation damage, celiac disease, anemia, dysostosclerosis, cerebral palsy, HIV infection, heavy metal intoxication etc.[3,20]

Conclusion

Tooth eruption is not an overnight event. The development of the dentition is characterized by phases of temporary discrepancies between the tooth size and jaw growth. The developing tooth does not move in a single direction, but in three dimensions and a gradual increase in the size of the tooth occurs within the alveolar bone before active eruption. It has been revealed that, the mechanism of tooth eruption is a complete, essentially time specific, biological interaction that occurs due to the coordination of multiple tissue elements in order to create the eruptive movement of tooth. Hence, awareness of the fundamental aspects, and thorough knowledge about tooth eruption and various events associated with it are necessary to understand the discrepancies in tooth eruption.

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