Histology of Tooth Development in 3D Animation Video and Images - A Preliminary Report

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Abstract

The process of tooth development is both, fascinating and well-described aspect of embryology. Although a big deal of the dental literature is being focused to the understanding of early stages of tooth development, still huge gap exist in our knowledge on how the dental hard tissues are formed, based on available images and descriptions. Tooth development process takes place in 3D form, inside our body. Therefore, histology should also be additionally explained with the help of additional 3D images and a video, which have not been reported so far. Methodology: Therefore, this brief article is a technical note and preliminary attempt to showcase 3D animation images and video of stages of tooth development which have been designed by the author herself using various the 3D animation softwares such as 3D max (Autodesk Media and Entertainment, San Rafael, California) and Adobe Premiere Pro 5.5 software which is a video-editing software (Adobe Systems, San Rafael, California).

Keywords: Bell, video, bud, cap, histology, images, root, softwares, stages, three dimensional, tooth development

Introduction

Odontogenesis is a highly synchronized and complex process that results in the genesis of tooth.[1] The comprehensive histological description is well described in the dental literature, but with the help of two-dimensional (2D) images using histological sections of tooth germs. It is extremely complex process of epithelial mesenchymal interactions occurring in tooth germ Therefore it is very difficult to understand and correlate with life like (3D) process of tooth formation in third dimension.[2,3]

Thus, there should be basic 3D animation video and images available for histological aspect of all oral tissues along with 3D description too, for better understanding especially for the students. This article is about the same related to the stages of tooth development.

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Methodology

This article is a brief technical note and preliminary attempt to showcase 3D images and video of stages of tooth development using various 3D animation softwares such as 3D max (Autodesk Media and Entertainment, San Rafael, California) and Adobe Premiere Pro 5.5 software which is a video-editing software (Adobe Systems, San Rafael, California).

All the stages of tooth development have been explained with the help of 3D images and videos based on histological description and images available in dental literature.

Stages of tooth formation in third dimension

The basic events of tooth morphogenesis were described well over 100 years ago. The earliest morphological sign of tooth formation is the appearance of the primary dental

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laminae (odontogenic bands), which is a stripe of thickened horseshoe-shaped sheet of epithelium marking the future tooth rows on the crest of the ridge.[4,5]

Histology of tooth development has been divided in four stages. In the following description, existing 2D histological description has been mentioned along with its third-dimensional description which is not available much in dental literature.

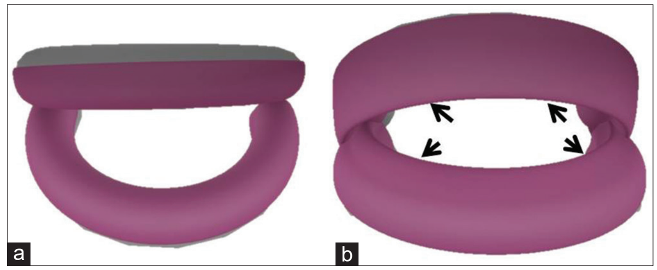

Figure 1: (a) Upper and lower alveolar arches. (b) Developing dental lamina along the crest of the ridge

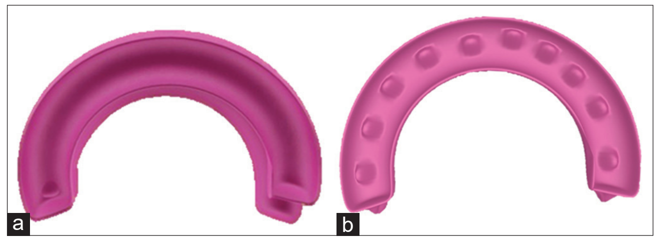

Figure 2: (a) Concave inner surface of oral mucosa. (b).Tooth germs arising from dental lamina in third dimension

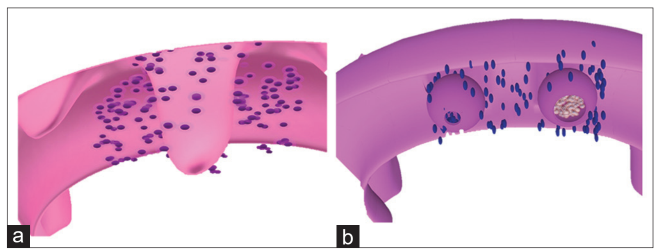

Figure 3: (a) Early bud stage arising from inner surface of mucosa. (b) Late bud stage in third dimension showing globular bud stages which are internally filled with cells. Dental sac cells are seen at the periphery of developing enamel organ.

Development of teeth

Histological aspect of dental lamina

The primary epithelial band gives rise first to the dental lamina on the inside of the dental arch and shortly afterwards, to the vestibular lamina, on the outside of the dental arch forms, both grow into the underlying ectomesenchyme.[6] Dental lamina in sections appears as vertical cord-like structure, but in 3D, it is a actually vertical sheet throughout the length of the alveolar arches. Both the primary epithelial band and dental lamina serve as a foundation for the future development of multiple individual tooth germs.[2,3]

Third-dimensional aspect of dental lamina

Both these lamina are horse-shoe shape sheet of epithelium arise from epithelial band, which grows downward within the jaw bone.[7,8] [Figure 1].

At 10 different points in each arch, at future location of deciduous teeth, cells of basal epithelium of dental lamina proliferate more, and invaginate into the underlying mesenchyme of developing jaw bone. The lower free end of the vertical extension of sheet of dental lamina shows series of globular/ spherical epithelial outgrowths or knobs due to proliferation of cells, into the underlying ectomesenchyme.[9] [Figure 2].

Each of these down growth from the dental lamina represents the beginning of the enamel organ of the tooth bud of a deciduous tooth. Secondary extension or branch from dental lamina gives rise to permanent tooth germ.

From this point, tooth development proceeds in three stages: The bud stage, cap stage, and bell stage.[3]

Histological aspect of bud stage

Initial globular enlargement of the free end of the dental lamina called as bud stage which consists of tall columnar cells at the circumference and centrally polygonal cells. Bud stage first appears in the anterior mandibular region.[2]

Third dimensional aspect of bud stage

Bud stage resembles a bud of flower having knob-like enlargement at the lower end and connecting vertical stalk (2D). Stalk basically is a vertical section of sheet of dental lamina and knob is developing tooth germ. This vertical stalk which runs along the alveolar arches attached to inner surface of oral mucosa through epithelial band. The knob is surrounded by cuff of ectomesenchymal condensation [Figure 3].

Histological aspect of cap stage

As the bud stage further develops, it takes on the shape which resembles a cap. The tooth bud of the dental lamina does not grow into a large sphere. Instead, there is unequal growth in different parts of the tooth bud, leading to the formation of a cap shape, which is attached to the overlying dental lamina.[10]

Third dimensional aspect of cap stage

The epithelial component of the tooth germ resembles a cap sitting on top of a spherical ectomesenchyme aggregation. It shows invagination which will be as depression externally, at the bottom surface, seen. This is seen as mild infolding starting from bottom of tooth germ and progressively deepens within the tooth germ. This depression is the future location of developing incisal edge and cusp of the developing teeth. Premolars and molars will have multiple such depressions. The whole tooth germ keeps sinking deeper into the underlying ectomesenchyme. (dental papilla and dental sac) [Figure 4]. Tooth germ contains stellate reticulum cells internally and columnar cells at the circumference.[2]

Histological aspect of bell stage

The shape of the enamel organ continues to change. The central depression deepens until the enamel organ assumes a shape resembling a bell. As the development takes place the dental lamina, which had thus far connected the enamel organ to the oral epithelium, becomes longer and thinner and finally breaks up and the tooth bud loses its connection with the epithelium. Tooth germ has various cell layers such has inner enamel epithelium, stellate reticulum, stratum intermedium, outer enamel epithelium.[2,11]

Third dimension of bell stage

At this stage, the connection between dental lamina and oral mucous membrane degenerate and enamel organ continues to grow inside jaw independently till the final crown forms and root growth starts. In the bell stage, the under surface of the tooth germ invaginates more, i.e., inner enamel epithelium shows infolding's and enters within the enamel organ and deepens. This invagination/concavity contains dental papilla [Figure 5]. The lower portion of outer enamel epithelium, all along the circumference of tooth germ loops and migrate inside to become inner enamel epithelium. This point of transition along the circumference is cervical loop appears like a ring in 3D and double layer loop in 2D.

The available area inside jaw bone for the each tooth germ is always fixed, which can accommodate only root of the final tooth. Therefore, in bell stage, when root formation starts, eruption happen simultaneously so that with each increment of root formation, tooth move outside the jaw, to create further space for remaining root formation.

During the root development, the invagination at the lower margin of the tooth germ appear like a disc initially in 3D, where outer enamel epithelium reflects inwards and later continues inwards as inner enamel epithelium. This invagination occurs along the circumference at future cementoenamel junction and takes a shape of folded ring. This folding or cervical loop at the margin of the enlarging bell-shaped enamel organ is a site of mitotic activity. This circular zone of marginal invagination at the bottom extends more downward and become double-layered barrel shape structure, filled with dental papilla centrally, and surrounded by dental sac tissue peripherally. This double-layered cylindrical soft-tissue sheath is called as hertwig's epithelial root sheath (HERS) [Figure 6].

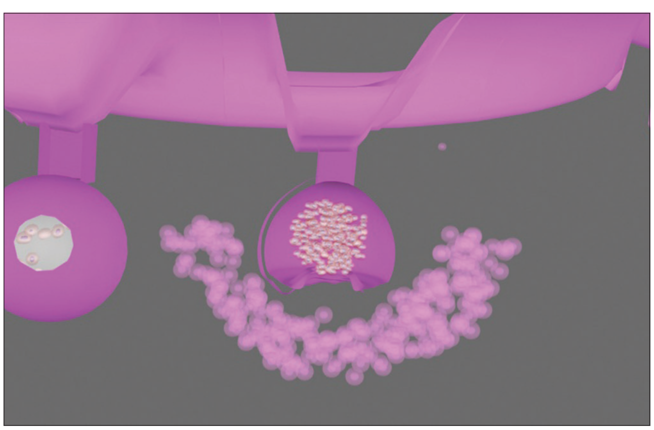

Figure 4: Shows section of cap stage filled internally with stellate reticulum and surrounded by dental sac in third dimension

Dentin forms circumferentially, throughout the length, on the inner surface of cylindrical wall of the sheath. After the formation of cylindrical dentinal nutritional supply is cutoff from dental papilla and HERS starts degenerating at multiple places and become perforated. Dental sac cells then comes in contact with newly formed dentin wall, through these perforations and starts differentiating into cementoblasts and depositing cementum tissue. As degenerations of HERS proceed the root is covered by cylindrical shapes dentin internally and cementum externally. Each increment of root length formation pushes the tooth out of the socket and result in eruption.

Histological aspect of root sheath development

After the crown has been completed, the inner and outer enamel epithelium at the base of the cervical loop proliferates to form a bilayer structure called HERS.

Third dimension of root sheath development

The free terminal part of the cylindrical epithelial root sheath bends horizontally towards the centre of the tooth germ at a 45° angle to form a disc like structure, the epithelial diaphragm. It reduces the size of the primary apical opening, which finally becomes the apical foramen. The epithelial diaphragm remains constant during root development because the continuity of the root sheath grows in length at the angle of the diaphragm and not at its tip. With each increment of root length, the crown begins to move outwards from the base of the crypt. This outward movement of the tooth provides space needed for continued root growth. As a result, the epithelial

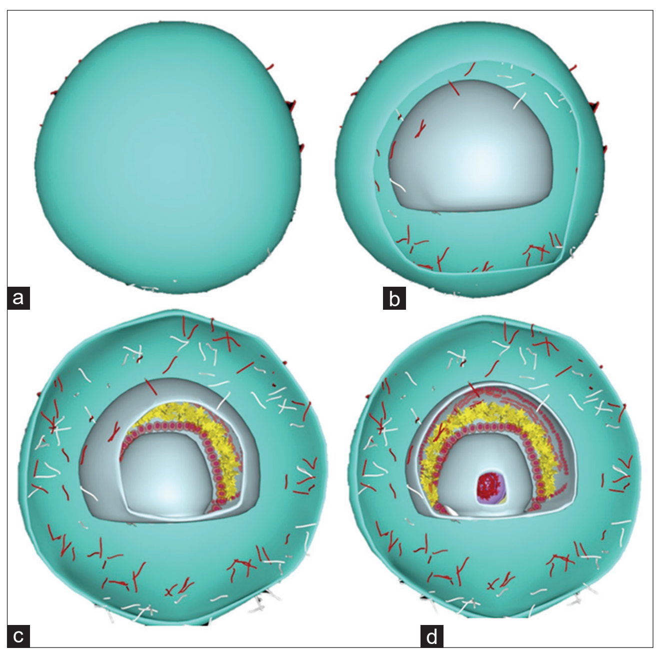

Figure 5: Bell stage with each layer sliced in third dimension. (a) Intact (b) dental sac opened. (c) Outer enamel epithelium opened (d) Inner enamel epithelium opened

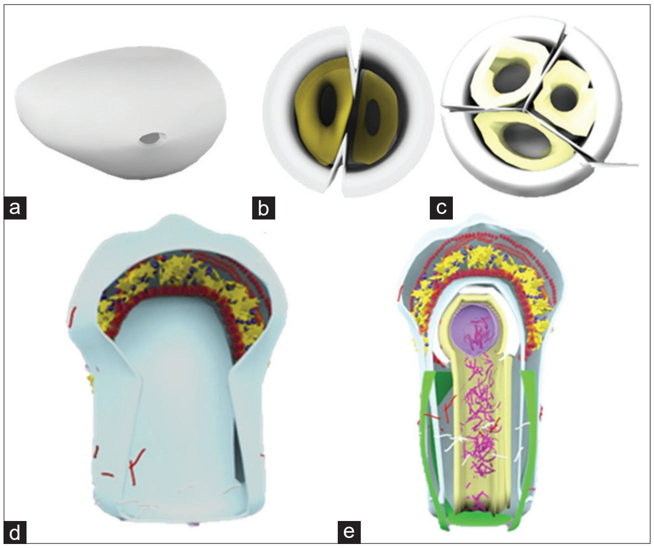

Figure 6: Shows section of root formation in third dimension. (a) Epithelial diaphragm at the base of the developing root. (b) T.S of 2 roots formation. (c) T.S of 3 roots formation. (d) L.S of root showing cervical loop and epithelial diaphragm. (e) L.S of root showing hard tissue formation

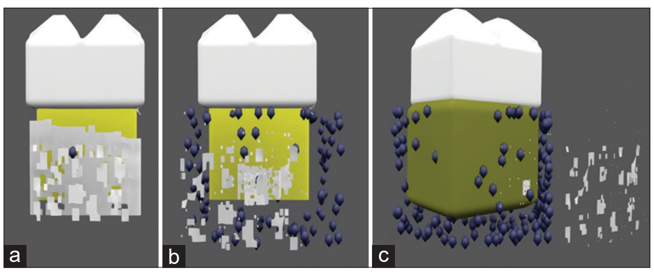

Figure 7: Shows root formation in third dimension. (a) Degeneration of hertwigs epithelial root sheath. (b) Detachment of hertwigs epithelial root sheath. (c) Cementum formation on dentin and cell rests of Malassez are getting detached

diaphragm maintains its position in relation to the base of the crypt. Thus root growth and eruption is a simultaneous process[12,13] [Figure 7].

All the above stages have been compiled in 3D animation video [Video 1].

Tooth development has attracted the attention of researchers since the 19th century. It became obvious even then that morphogenesis could not fully be appreciated from 2D histological sections. Therefore, methods of three-dimensional (3D) reconstructions have also been employed by Peterkova *et al*, to visualize the surface morphology of developing structures and to help appreciate the complexity of early tooth morphogenesis but still very difficult to understand as they too are static.[14]

Conclusion

The past decades of extensive research have provided the current understanding of tooth development. Throughout the development of teeth, epithelial-mesenchymal interaction plays an important role in orchestrating the cellular events that take place at different time points, enabling multiple cell types to carry out their precise roles to form teeth without error. This complex molecular regulatory network is explained by images in two dimensions. However, it is very difficult to understand by the readers to imagine tooth development in life like process which exists inside our body. Therefore, 3D videos and images and text for same would provide new insights into better understanding of odontogenesis, as discussed in this article.

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Conflicts of interest

There are no conflicts of interest.

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