PHYSIOLOGIC TOOTH MOVEMENT

ERUPTION

TEETHING
Objectives

To Describe phases of tooth eruption:
To explain the different types of tooth movements during eruption phases
To understand the mechanism of tooth eruption
To know normal events occurring during different eruption phases
To Describe the initial growth of the tooth and the compensational changes that occur in the surrounding, overlying and underlying tissues.
To discuss clinical considerations of tooth eruption
Definition
Phases of tooth movement
Direction and types of Tooth Movement
A. PRE-ERUPTIVE Tooth movement
Movements of the deciduous tooth germs
Movement of Permanent Teeth
B. PREFUNCTIONAL ERUPTIVE PHASE
Five major events take place during this phase:
1. Changes in tissues overlying the tooth:
   Gubernacular canals
   Gubernacular cord (Gubernaculum dentis)
2. Changes in the tissues around teeth
3. Changes in the tissues underlying the teeth
MECHANISM(S) OF TOOTH ERUPTION
1- ROOT FORMATION THEORY:
2- BONE REMODELING THEORY:
3- VASCULAR PRESSURE THEORY
4- PERIODONTAL LIGAMENT TRACTION THEORY
Sequence of eruption of Deciduous teeth
Sequence of eruption of permanent teeth
C. POST ERRUPTIVE PHASE (FUNCTIONAL ERUPTIVE PHASE):
Histology of Post eruptive tooth movement:
1- Movements to accommodate growth of the jaws.
2- Movements to accommodate for continued occlusal wear.
3- Movements to accommodate interproximal wear.
ROLE OF DENTAL FUCELICLE WITH REDUCED ENAMEL EPITHELIUM TISSUE TENSION THEORIES:
CLINICAL CONSIDERATION
Definition
is the axial or occlusal movement of the tooth within and from its developing site through the bone of the jaw and overlying mucosa to appear in the oral cavity and reach its functional position in the occlusal plane.

is a complex and multistep process, which includes different types of tooth growth and movements within the bony crypt in order for the tooth to erupt into the genetically designated area of the maxilla or mandible.

To accomplish eruption, bone remodeling by osteoclasts (resorption of bone) and osteoblasts (bone deposition) must take place in a coordinated manner. Most important is the removal of bone overlying the crypt, which forms the eruption pathway. In experimental studies, it has been shown that without eruption pathway formation, the tooth will not erupt.
1- **Axial (occlusal) movement:** It is an occlusal movement in the direction of the long axis of the tooth.

2- **Bodily movement:** Bodily movement is a shift of the entire tooth germ, which causes bone resorption in the direction of tooth movement and bone apposition behind it.

**Drifting movement:** bodily movement in a distal, mesial, lingual or buccal directions.
3- **Tilting or tipping movement**: movements around a transverse axis.

4- **Rotatory movement**: movement around a longitudinal axis.

5- **Eccentric growth movement**: refers to relative growth in one part of the tooth while the rest of the tooth remains constant, the root elongates yet the crown does not increase in size. As a result, the center of the tooth changes.

Or Movement where one part remains fixed while the rest continues to grow leading to change in the center of the tooth germ.
Phases of Physiological tooth movement or Pattern of Eruption

Pre-eruptive phase

Eruptive prefuctional phase

Post-eruptive Functional phase
A. PRE-ERUPTIVE TOOTH MOVEMENT

<table>
<thead>
<tr>
<th>Starts:</th>
<th>Ends:</th>
<th>Type of movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early bell</td>
<td>Begin of root formation</td>
<td>Bodily, Eccentric</td>
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</table>

* It starts at the beginning of tooth development and ends when the crown formation is completed.

The movements of the developing and growing tooth germs within the alveolar process before root formation. During this phase, the growing teeth move in various directions to maintain their position in the expanding jaws. This is accomplished by both *bodily* movements and *eccentric* growth.

These movements relate to the adjustments that each crown must make in relation to its neighbor and to the jaw as they increase in width, height and length.
MOVEMENTS OF THE DECIDUOUS TOOTH GERMS

- **When Increase in jaw length**
  - Anterior deciduous teeth drift **forward** and second deciduous molar tooth germs drift **backward**.
- **Increase in jaw height**
  Tooth germs move in vestibular direction (upward or downward).
- **Increase in jaw width**
  Tooth germs move (outward) facially.
1- The permanent incisors and canine first develop lingual to the deciduous tooth germ at the level of their occlusal plain and in the same bony crypt.

2- As the deciduous predecessors erupt, the permanent tooth germs move to a more apical region of their deciduous predecessor and occupy their own bony crypts.
1- The permanent premolars begin their development lingual to their predecessors at the level of their occlusal surface and in the same bony crypts.

2- Later, they are found between the divergent roots of the deciduous molars.

3- At the end of the pre-eruptive phase, the tooth germs of the permanent premolars are found below the roots of the deciduous molars in their own crypts.
Permanent Molars

- Maxillary tuberosity
- Base of the ramus
The permanent molars undergo considerable movements adjusting positions as the jaws grow:

1- The upper molars develop in the tuberosities of the maxilla, with their occlusal surfaces facing distally. They swing around only when the maxilla has grown sufficiently to provide the necessary space.
2- The lower molars develop in the base of the mandibular rami and their occlusal surfaces facing mesially. They only become upright as rooms for them become available.
B. PREFUNCTIONAL ERUPTIVE PHASE

It begins with the initiation of root formation and ends when the teeth reach the occlusal plane. (Emergence phase)
Eruptive Phase

**Starts:**
Onset of root formation

**Ends:**
Tooth reach occ plane

**Events:**
- Crown completed
- Root formation
- Development of PDL and supp
- Development of dentogingival junction.

**Type of movement**
All types of movements
1- **Secretory stage** of amelogenesis (crown) is completed.

2- **Intra-osseous stage** at the beginning of root formation. Root is completed in this phase.

3- **Supra-osseous stage** when the erupting tooth moves occlusally through the bone of the crypt and the connective tissue of the oral mucosa, so that the reduced enamel epithelium covering the crown comes into contact with the oral epithelium.

As this occurs, the reduced enamel epithelium of the crown proliferates and forms firm attachment with the oral epithelium. A fused double epithelial layer over the erupting crown is thus formed.
4- **Emergence stage** (clinical crown appear) when the tip of the crown of the tooth appears in the oral cavity by breaking through the center of the double layered cells. The crown erupts further, and the lateral borders of the oral mucosa become the dentogingival junction. The reduced enamel epithelium, now surrounding the crown like a cuff, and known as the junctional or attachment epithelium. When the tip of the crown appears in the oral cavity, about one half to three quarters of the root is formed.

5- **The erupting stage** tooth continues to move occlusally at a maximum rate and there is gradual exposure to more of the clinical crown. Occlusal movements are the result of active eruption. As the tooth moves occlusally, gradual exposure of the clinical crown is accomplished through separation of the attachment epithelium from the crown and the resulting apical shift of the gingiva.
**ACTIVE ERUPTION**: It is the actual movement of the tooth from its developmental site to its position in the dental arch.

**PASSIVE ERUPTION**: Does not involve tooth movement but occurs due to apical recession of gingival tissue exposing more tooth structure into the oral cavity.

**ANATOMICAL CROWN**: It is part of the tooth which is covered by enamel.

**CLINICAL CROWN**: is the part of the tooth which is seen in the oral cavity.
Mechanism(s) of Tooth Eruption

- The nature of the intrinsic forces involved in active tooth eruption is not fully understood.

- Available experimental evidence seems to support factors related to tissue tension theories.

- Experiments where an erupting tooth is wired to the lower border of the mandible show that despite immobilizing the tooth, an eruptive path is formed by resorption of the overlying bone.

- However, if the dental follicle associated with an erupting tooth is removed, no such pathway in bone is formed and tooth does not erupt.

- This finding coupled with the fact that human teeth erupt according to a specific chronology imply the presence of a programmed mechanism that leads to tooth eruption. Such mechanism is probably a multifactorial one that includes control by specific gene(s), hormones as well as several growth factors.
Mechanism of eruption

- Bone Remodeling theory
- Root formation theory
- Vascular pressure theory
- PDL traction theory

Role of the dental follicle with reduced enamel epithelium in tooth eruption.
This theory postulated that proliferating root impinges upon a fixed tissue thus converting an apically directed force into occlusal movement.
- **However, It is unlikely the cause of tooth eruption since:**

- Rootless teeth erupt.

- Experimental resection of root forming tissues does not stop eruptive tooth movement,

- Some teeth moves greater distances than the length of their roots and the eruptive movement can occur after completion of root formation.

- It is also important to know that initial root formation results in bone resorption at the base of the socket. For root formation to result in an eruptive force, the growth of the root requires the presence of a fixed base. Unfortunately, the structure described as *Cushioned hammock ligament* before, and was believed to be a fixed base for the growing root to react against, is now proven to be the pulp delineating membrane that runs across the apex.
It was proposed that selective deposition and resorption of bone brings eruption. Whether the bony remodeling that occurs around teeth causes or is the effect of tooth movement is not known.

**2- BONE REMODELING THEORY:**

It proposes that a local increase in tissue fluid pressure in the periapical region is sufficient to move the tooth. However, experimental elimination or isolation of the periapical vasculature does not prevent tooth eruption. Tissue fluid pressure as an eruptive force must always be considered as differential pressure exists below and above an erupting tooth has been reported.

**3- VASCULAR PRESSURE THEORY:**
This theory proposes that the cells and fibers of the periodontal ligament pull the tooth into occlusion.

When the normal architecture of the ligament is distorted experimentally, a retarded eruptive movements result

It is suggested that eruptive movement could be brought about by a combination of events involving a force initiated by the fibroblasts. This force is transmitted to the extracellular compartment via fibronexues and to collagen fiber bundles, which aligned in an appropriate inclination brought about by root formation, bring about tooth movements. These fiber bundles must have ability to remodel for eruption to continue. This suggestion is biologically the most feasible as isolated fibroblasts have been shown to have contractile properties and also is responsible for the contraction that occurs during wound repair.
ROLE OF DENTAL FOLLICLE WITH REDUCED ENAMEL EPITHELIUM:

1- Forming eruption pathway:

A- Dental follicle produce Colony stimulating factor-1 that stimulates differentiation of osteoclast.
B- The Reduced enamel epithelium initiates a cascade of intercellular signals that recruit osteoclasts to the follicle (for bony remodeling).
C- Reduced enamel epithelium also secretes proteolytic enzymes which assist in the breakdown of the connective tissue above the tooth to produce a path of least resistance.
2- *Dental follicle provides osteoblasts* that forms the bone trabeculae apical to the tooth and *conduits for Osteoclasts* that derives from monocyte through the vascular supply.

Experiment s has established that it is an absolute requirement.

3- *Dental follicle contains epidermal growth factors, prostaglandins, transforming growth factors* and other influencing factors which help in tooth eruption.
Role of dental follicle, periodontal ligament and contraction of periodontal fibroblasts:
- Experimental evidence points out the existence of factors other than pressure by the erupting tooth that leads to bone resorption.
- Such factors either reside and/or act on components of the dental follicle.
- At the molecular level researchers were able to isolate specific follicular proteins that were only expressed during certain times within the prefunctional eruptive stage.
- Immunocytochemical studies revealed that the reduced dental epithelial cells express epidermal and transforming growth factors. These factors stimulate dental follicular cells to express colony stimulating factor 1 (CSFI) which recruit osteoclasts needed for bone remodeling.

This is another example of epithelial/mesenchymal interactions.
In addition to the essential roles of the dental follicle and one of its derivatives, namely the periodontal ligament, the contractile potential of the fibroblasts was proposed as a contributing factor.

- The tooth movement is probably caused by contractile elements in fibroblasts such as specialized junctions between fibroblasts, fibronexus connections between fibroblasts and collagenous fiber bundles (a fibronexus is a specialized structure involving attachment between cytoplasmic filaments, fibroblast plasma membrane and extracellular matrix elements including fibers).
In conclusion, it appears that there is no single cause of tooth eruption.

Experimental evidences clearly suggest that the dental follicle is an important element in tooth eruption.

Eruptive tooth movement is multifactorial where Dental follicle playing an important part to initiates the process and other factors facilitates.
The Pre-functional eruptive stage is characterized by significant changes in the tissues:

1- Overlying the tooth.

2- Around the tooth.

3- Underlying the tooth.
1. Changes in tissues overlying the tooth:

- The Dental Follicle forms *eruption pathway*. This is more prominent in erupting permanent teeth.

- **Histologically:** Numerous monocytes and osteoclasts, CT fibers disappeared, cells degenerated, Bl.V. fewer, terminal nerves degenerated.

- These changes result from:
  1. Loss of Bl. supply.
  2. Degradation enzymes.
They are **holes in the jaws on the lingual aspects of the deciduous teeth** that once contained the cords. As the successional tooth erupts, its gubernacular canal is widened rapidly by local osteoclastic activity, delineating the eruptive pathway for the tooth.
Gubernacular cord (Gubernaculum dentis):

It is a strand of fibrous tissue containing remnants of the dental lamina through which the erupting permanent successor tooth retains its connection with the lamina propria of the oral mucosa.
2. Changes in the tissues around teeth

- Increase in height and change in shape of the alveolar bone.
- Increase collagen fibers extending between the forming root and the alveolar bone surfaces.
- Remodeling of the alveolar bone of the crypt to accommodate the forming root. As the large crown moves occlusally the bone fills in to conform to the smaller root diameter.
Remodeling of PDL to accommodate continued eruptive movement (achieved by fibroblasts). Contractile property of fibroblast is well developed in PDL and exert stronger contractile movement. Intermediate filaments that consist of contractile proteins. They also exhibit frequent cell-to-cell contacts of the adherence type and a further specialization involving the cell membrane, the fibronexus. This describes a morphologic relationship between the intracellular filaments of the fibroblast, transmembrane proteins, which produce an increased density of fibroblast cell membrane, extracellular filaments, and fibronectin. Fibronectin is a sticky glycoprotein that can stick to a number of extracellular components, including collagen. Ultrastructurally, fibronexus consists of intracellular actin filaments and extracellular fibronectin filaments associated with subplasmalemmal plaque material that contains proteins such as vinculin, talin, alphactin and integrin. Finally, the ligament fibroblast has the ability to ingest and degrade extracellular collagen while forming.
3. **Changes in the tissues underlying the teeth:**

- As the tooth erupts, space is provided for the root to lengthen, primarily because of:
  - crown moving occlusally and increase in height of the alveolar bone.
  - Fine bony trabeculae appear in the fundic area. They compensate for tooth eruption and provide some support to the apical tissues. This is called **bony ladder**.

- At the end of the prefunctional eruptive phase, the bony ladder is gradually resorbed, one plate at a time to make spaces for the developing root tip.

- Root completion continues for a considerable time after the teeth have been in function. This process takes from 1 to 1.5 years in primary teeth and from 2 to 3 years in permanent teeth.
The rate of tooth eruption depends on the phase of movement.

Intraosseous phase: 1 to 10 μm/day

Extraosseous phase: 75 μm/day

Environmental factors affecting the final position of the tooth:

Muscular forces
Thumb-sucking
The 6/4 rule for primary tooth emergence means that from birth, 4 teeth emerge for each 6 months of age. Thus, 6 months, 4 teeth; 12 months, 8 teeth; 18 months, 12 teeth; 24 months, 16 teeth; and 30 months, 20 teeth.

1. 6 months: 4 teeth (lower centrals & upper centrals)
2. 12 months: 8 teeth (1. + upper laterals & lower laterals)
3. 18 months: 12 teeth (2. + upper 1st molars & lower 1st molars)
4. 24 months: 16 teeth (3. + upper canines & lower canines)
5. 30 months: 20 teeth (4. + lower 2nd molars & upper 2nd molars)

Summary

1. By 5 months in utero, all crowns started calcification
2. By 1 year old, all crowns completed formation
3. By 2.5 years, all primary teeth erupted
4. By 4 years old, all primary teeth completed root formation
Rules of “sixes” in dental development

6 weeks old in utero: beginning of dental development
6 months old: emergence of the first primary tooth
6 years old: emergence of first permanent tooth

The rules of “Fours” for permanent tooth development (3rd molars not included)

At birth, four 1st molars have initiated calcification
At 4 years of age, all crowns have initiated calcification
At 8 years, all crowns are completed
At 12 years, all crowns emerge
At 16 years, all roots are complete
## Sequence of eruption of Deciduous teeth

### Chronology of the Human Primary Dentition

<table>
<thead>
<tr>
<th>Jaw</th>
<th>Tooth</th>
<th>Calcification begins</th>
<th>Crown completed post-natally</th>
<th>Time of emergence</th>
<th>Root completed (yrs)</th>
<th>Emergence sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(mo in utero)</td>
<td>(month)</td>
<td>(month)</td>
<td>(year)</td>
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</tr>
<tr>
<td>Max.</td>
<td>i¹</td>
<td>3-4 months</td>
<td>2</td>
<td>7-10</td>
<td>2.5</td>
<td>2</td>
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<tr>
<td></td>
<td>i²</td>
<td>4 months</td>
<td>2-3</td>
<td>8-11</td>
<td>2.5</td>
<td>3</td>
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<tr>
<td></td>
<td>c¹</td>
<td>4-5 months</td>
<td>9</td>
<td>16-19</td>
<td>3.5</td>
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<tr>
<td></td>
<td>m¹</td>
<td>4 months</td>
<td>6</td>
<td>12-15</td>
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<tr>
<td></td>
<td>m²</td>
<td>5 months</td>
<td>11</td>
<td>25-28</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Mand.</td>
<td>i₁</td>
<td>3-4 months</td>
<td>2-3</td>
<td>6-8</td>
<td>2.5</td>
<td>1</td>
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<tr>
<td></td>
<td>i₂</td>
<td>4 months</td>
<td>3</td>
<td>9-13</td>
<td>2.5</td>
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<td>12-16</td>
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<td>6</td>
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<tr>
<td></td>
<td>m₂</td>
<td>5 months</td>
<td>10</td>
<td>20-26</td>
<td>3.5</td>
<td>9</td>
</tr>
</tbody>
</table>

(modified from Avery, p.121, Figure 7-1)
### Sequence of eruption of permanent teeth

<table>
<thead>
<tr>
<th>Jaw</th>
<th>Tooth</th>
<th>Calcification begins</th>
<th>Crown completed (yr)</th>
<th>Time of emergence (yrs)</th>
<th>Root completed (yrs)</th>
<th>Emergence sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>I1</td>
<td>3-4 months</td>
<td>4-5</td>
<td>7-8</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>I2</td>
<td>10-12 months</td>
<td>4-5</td>
<td>8-10</td>
<td>10-11</td>
<td>6</td>
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<td></td>
<td>C</td>
<td>4-5 months</td>
<td>6-7</td>
<td>11-13</td>
<td>14-15</td>
<td>12</td>
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<tr>
<td></td>
<td>P3</td>
<td>1-2 yrs</td>
<td>6-7</td>
<td>10-12</td>
<td>12-14</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>2-3 yrs</td>
<td>7-8</td>
<td>10-12</td>
<td>13-14</td>
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<tr>
<td></td>
<td>M1*</td>
<td>At birth</td>
<td>4-5</td>
<td>6-7</td>
<td>9-10</td>
<td>2</td>
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<td></td>
<td>M2</td>
<td>2-3 yrs</td>
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<td>M3</td>
<td>7-9 yrs</td>
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<td>Mand.</td>
<td>I1</td>
<td>3-4 months</td>
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<td>6-7</td>
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<td>3</td>
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<td>I2</td>
<td>3-4 months</td>
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<td>4-5 months</td>
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<td></td>
<td>M3</td>
<td>8-10 yrs</td>
<td>12-16</td>
<td>17-20</td>
<td>18-25</td>
<td>15</td>
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</tbody>
</table>

6-1-2-4-5-3-7-8
(6-1)-2-4-3-5-7-8
Post eruptive phase

**Starts:**
When the tooth reach oocc plan

**Ends:**
End of the life span of the tooth

**Events:**
- bone,
- cementum,
- PL
- Remodeling

**Type of movement**
All types of movements

- **Histology of Post eruptive tooth movement:**
  1- Deposition of bone at:
     - Alveolar crest.
     - socket base.
  2- Deposition of cellular cementum.
  3- Remodeling of Bone and PDL.
1 - Movements to accommodate growth of the jaws.

- Completed at the end of the 2\textsuperscript{nd} decade, (\textit{most active in young adult between ages 14 to 18 years}) when jaw growth ceases.
- Achieved by new bone formation at alveolar crest and socket floor to keep pace with the increasing height of the jaws.
- Readjustment of tooth sockets occurs \textit{between the ages of 14 and 18 years}, when active movement of the tooth takes place. The apices of the teeth \textit{move axially} 2 -3 mm away from the inferior dental canal (regarded as a fixed reference point).
- It occurs earlier in girls than boys.
- Related to \textit{burst of condylar growth} that separates the jaws and teeth, permitting further eruptive movement.
Axial movement similar to eruptive tooth movements.

After root completion.

Continued cementum deposition around the apex of the tooth root. However, the deposition of cementum in this location occurs only after the tooth has moved.
3- Movements to accommodate interproximal wear.

- Wear also occurs at the contact points between teeth on their proximal surfaces; its extent can be considerable (more than 7 mm in the mandible).

- This interproximal wear is compensated for by a process known as *mesial or approximal drift*.
  1. Anterior component of occlusal force.
  2. Contraction of transseptal ligament.
  3. Soft tissue pressure (cheeks and tongue) may push teeth mesially.
In the primary dentition, eruption occurs earlier in boys than in girls. While in the permanent dentition, eruption in girls precedes that in boys.

In general, the mandibular teeth precede the maxillary teeth in the permanent dentition.

Under normal conditions, teeth tend to be delayed rather than early in eruption. Differences of 1 or 2 months on either side of the noted range should not be considered abnormal.

Homologous teeth in the same arch appear in close approximation of time.

Infants who attain delayed incisor teeth, the remaining teeth may not arrive late.

A tooth generally takes from 1.5 to 2.5 months from the beginning of clinical eruption until it reaches the occlusal plane.

Canine usually takes the longest time to erupt.
It has been shown that the moment a tooth breaks through the oral epithelium, an acute inflammatory response occurs in the connective tissue adjacent to the tooth. This is seen even in the germ-free animals and is seen in varying degrees around all teeth throughout life. Clinically, as teeth break through the oral mucosa, there is often some pain, slight fever, and general malaise, all signs of an inflammatory process. In infants these symptoms are popularly called “teething.”

**Factors affecting tooth eruption**

**Local factors:**
- Fibromatosed gingiva
- Premature loss of deciduous
- Missed tooth
- Ankylosed deciduous
- Impacted tooth

**General or systemic factors**
- Hormonal disturbances as hyper or hypo thyrodism
- Nutritional disturbances like hypo proteneimia or hypo vitaminosis