Chapter

Organic Matrix of Enamel and Dentin and Developmental Defects

Eui-Seok Lee, Puneet Wadhwa, Min-Keun Kim, Heng Bo Jiang, In-Woong Um and Yu-Mi Kim

Abstract

The anatomical crown of the tooth is covered by enamel and root is covered by cementum. The dentin forms the major part of the tooth. The dentin structure is very similar to that of the bone both physically and chemically which is why many scientists have wondered about using its properties for developing a novel bone graft material. In contrast with hard and brittle enamel dentin is viscoelastic. The organic structure of dentin which is about 35% is composed of mainly type *I* collagen embedded in mucopolysaccharides ground substance. Approximately half of the non-collagenous composition consists of hyperphosphorylated proteins. The acidic glycoproteins, Gla-proteins, serum proteins, proteoglycans etc. composes the remaining part. The dentin matrix consists of many similar proteins as that of bone like dentin phosphoprotein, dentin sialoprotein etc.. The matrix also consists of many growth factors. Any external disturbance like an infection, trauma, calcium or phosphorous metabolic changes can lead to defective amelogenesis. Mutational changes can lead to defect in dentin. An early diagnosis can result in a satisfactory treatment plan contributing to functional and esthetical compensation.

Keywords: Enamel matrix, Dentin matrix, Tooth proteins, Growth factors, Tooth developmental defects

1. Introduction

Enamel and dentin constitute different concentrations of organic, water and mineral contents. This accounts for their specific physical-mechanical properties and their integration allow the tooth to be functionally stable in adverse oral conditions [1]. Dentin tissue underlines the enamel and constitutes the bulk of the tooth. The inorganic to organic ratio is different in various tissues, these variations affect the properties of these tissues. The enamel is tougher and most highly resistant to force in comparison to other hard tissue in the body owing to its high inorganic content. On the other hand the dentin with high organic content serves as a resilient layer under enamel and cementum [2]. Enamel shows higher mineralization than cementum as there is more carbon 49% (wt) in cementum than enamel 3% (wt). Enamel being the hardest tissue and dentin being softer whereas X-ray diffraction (XRD) shows cementum has poorest crystallinity. Following decalcification process for separation of organic and inorganic content the organic components of the dentin are retained thereby maintaining the dentin shape. However due to 90% mineral content of the enamel it is lost after decalcification.

2. Enamel

Tooth enamel possess remarkable structural and mechanical properties making it an unique tissue. Tooth enamel is a complex mineralized tissue comprising of long and parallel apatite crystals configured into decussating enamel rods [3, 4]. The enamel consists of 96% inorganic and 4% organic and water content and is the most mineralized tissue. The organic content of enamel is less than that of dentin. The organic content consist of some unique proteins present only in enamel and lipids [5]. The enamel is formed only once before the eruption of the tooth. Following eruption the tooth organ permanently loses the ability to form new enamel [3].

Being highly mineralized enamel could be expected to be brittle and have low fracture resistance. However, the experimental studies proved that the fracture toughness of enamel is equivalent to or even better than some tough ceramics [6, 7].

2.1 Enamel proteins

During the development of enamel, ameloblasts secrete enamel matrix protein. Proteins are large complex molecules that are required for the structure, function and regulating body's tissues and organs. Enamel matrix proteins bind to the hydroxyapatite structuring the enamel and modulating crystal growth [8, 9]. Initial developing enamel matrix constitutes 60-70% water, 20-30% proteins and 15-20% of mineral ions. Mineralization process leads to resorption of enamel proteins and water leaving very little amount of organic content in matured enamel [3]. Major components of the enamel matrix protein (EMP) are the amelogenins constituting greater than 90% of all the organic content in the enamel [10, 11]. The other type of protein group is the non – amelogenin including enamelins, tuftelin and sheathlins. Other than these two enzymes, matrix metalloproteinase (MMP)-20 and enamel matrix serine proteinase (EMSP)-1 are also present in the EMP (**Figure 1**) [10].

Enamel proteins consist of 1-2% of the total composition. These proteins are located mainly at the enamel rods interface. The proteins play a role in modulation of the stress in enamel and contributes to the elastic and viscoelastic behavior [12]. Any kind of damage or denaturation of the enamel or dentin non-collagenous proteins can decrease the durability of the tooth [12]. Tooth whitening procedures or treatment with potassium hydroxide leads to loss of enamel proteins causing enamel to be more prone to fracture [12, 13]. Radiation therapy for treatment of oral cancers is also known to damage the enamel proteins [12]. In a study the enamel proteins were extracted using potassium hydroxide treatment from the

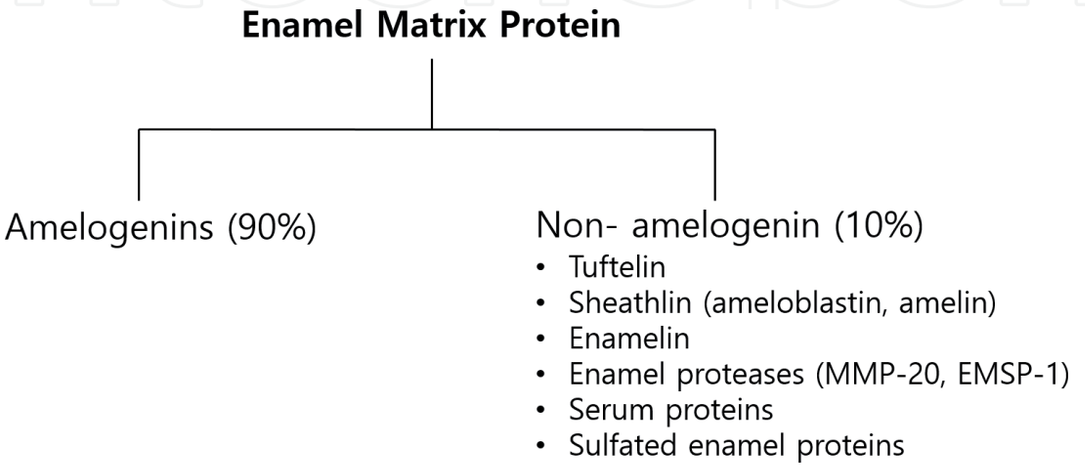

Figure 1.
Types of enamel matrix proteins.

enamel sections of the molar cusps. The results showed a 40% reduction in fracture toughness in comparison with a fully proteinized control. The organic content of the enamel is very small, but it is of importance crack growth toughening. This is because it helps in forming unbroken ligament and fortify its efficacy [14].

The synthesis and secretion of the organic extracellular matrix is controlled by ameloblasts and deposited along the dentino-enamel junction which eventually controls enamel biomineralization [15].

Amelogenins are hydrophobic in nature, they are rich in proline (25%), glutamine (14%), leucine (9%) and histidine (7%) amino acid residues [4, 15]. Amelogenin functions in regulating orientation, shape and length of enamel crystals [16]. Tuftelin is suggested to function at the level of ameloblast differentiation, it may play a role in extracellular matrix secretion. Tuftelin is also expressed in different soft tissues, which suggest it may have multifunctional role [17]. Ameloblastin also known as sheathlin and amelin present in Tomes' processes of the secretory ameloblasts the sheath space between rod and inter-rod enamel suggest that this protein may play a role in biomineralization. Enamelin is also believed to play a role in enamel

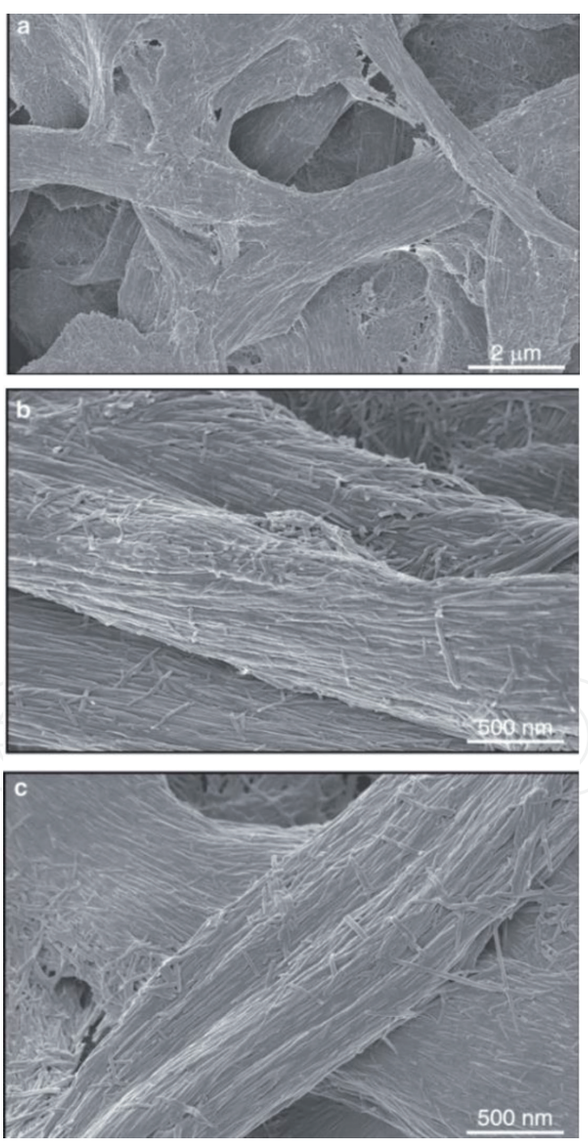

Figure 2.
Scanning electron micrograph images of engineered enamel. In this study apatite was grown within a decellularized enamel protein matrix, resulting in decussating enamel prisms containing distinct and separated individual enamel crystals. A SEM image overview of the engineered enamel apatite, b depicts parallel bundles of enamel crystals, and c depicts newly formed decussating enamel rods [3]. Figure adapted from Pandya M et al. (2019).

biomineralization. Enamelin is hydrophilic and an acidic protein rich in glycine, aspartic acid and serine [4]. The enamel proteins with unique properties requires specific proteases for their removal during enamel maturation whose spatiotemporal expression is impeccably regulated. This requirement is met by serine protease kallikrein-4 and MMP20 [18]. Enamel proteases processes secreted amelogenins, ameloblastin and enamelin in the matrix and eventually degrades and remove them from the mineralizing matrix when maturation of amelogenesis occurs. The sulfated enamel proteins are present in very small amount in the enamel matrix [15].

2.2 Applications of enamel matrix proteins

Enamel matrix derivative (EMD) is approved by FDA to be used as a material for periodontal regeneration since 1997 [19]. EMD is commercially obtained by heat treated lyophilized proteins that are isolated from porcine enamel at specific stage of development [20]. Emdogain, a mixture of enamel matrix proteins mainly composed of amelogenin is used for repair of hard and soft periodontal tissues [11, 21–23]. Emdogain has shown similar results to guided tissue regeneration with added advantage of easy to use with minimal complications [23].

Owing to its unique properties like toughness and relative fracture resistance researchers are focusing on developing an enamel-like biomaterial. Enamel biomimetics hold a great promise as structural components in a wide range of fields for biomedical and engineering applications. Some examples are like tooth repair, restoring a orthopedic defect site, functional insulator components, brakes and exhaust pollutant filters [3, 24]. Enamel proteins and calcium phosphate growth solutions seems to be a convincing formulation for biologically synthesizing tooth enamel. Based on the established role of enamel proteins, using an EMP researchers were successfully grew elongated and parallel apatite crystals within decussating enamel prisms (**Figure 2**) [3]. The research until now using biochemical approaches can only mimic limited features of apatite and calcium phosphate crystal growth.

3. Dentin

The dentin consists of 65% inorganic and 35% organic and water content. The presence of more organic content in dentin than enamel makes it very similar to that of bone. The organic part of dentin is composed of collagenous fibrils embedded in ground substance of mucopolysacchrides [5]. Type I collagen is the principal type of collagen in dentin. It contributes about 90% of the organic content, the remaining 10% contains several proteins and proteoglycans, acidic glycoproteins referred to as non-collagenous proteins [25, 26]. Also type I collagen is abundantly present organic constituent of the bone extracellular matrix [27]. The collagen fibrils form a scaffold network and are densely mineralized. The dentin consists of little amounts of type V and III collagen. The odontoblasts synthesize and secretes the non-collagenous proteins as well collagen fibrils [28].

Dentin constitutes tubules ranging in size of micrometer and surrounded by highly mineralized peritubular dentin, embedded in a matrix rich in collagen called intertubular dentin. Lamina limitans a sheet-like structure divide the peritubular and the intertubular dentin and primarily composed of proteoglycans protein cores. The proteoglycans contribute to mechanical behavior of dentin. They link the collagen fibrils securing the collagenous network together [12]. Peritubular dentin is primarily made of glycosaminoglycans and lacks collagen fibrils [29]. Intertubular matrix chiefly constitutes type I collagen fibrils with non-collagenous proteins and proteoglycans which forms a three-dimensional organic network buttressed by apatite mineral crystallites [30].

The adhesive systems used for dentin bonding rely on formation of a hybrid layer. This hybrid layer is formed by demineralized collagen fibrils reinforced by resin matrix. As the resin monomers are unable to infiltrate the mineralized tissues, so adhesive bonding systems are used which has an acid, primer and an adhesive. The acid helps in removing mineral crystals and exposing the collagen. The primer which is a hydrophilic solution permits the infiltration of resin monomer into the demineralized dentin. Finally, the adhesive consisting of a mixture of monomers penetrates the treated surface thereby forming mechanical adhesion with dentin. Removing the unbound water from hybrid layer and suppressing the endogenous enzymatic activity have helped in increasing biocompatibility by inhibiting degradation of the hybrid layer [31].

3.1 Dentin proteins

The dentin matrix and bone proteins are similar. Type I collagen designs an effective and instructional template for guiding deposition of calcium phosphate polymorphs and subsequently transforming into crystalline hydroxyapatite crystals. The highly complex process of hydroxyapatite nucleation and collagen mineralization is also controlled by non-collagenous proteins. The amount of these non-collagenous proteins in dentin and bone is small, but they play an indispensable role in bone formation and remodeling. Some examples of non-collagenous proteins found in both are osteocalcin, osteopontin and bone sialoprotein. The dentin matrix proteins are of interest because of their calcium binding property in the extracellular matrix which leads to calcification of tissue [32]. Many studies have shown similarities between dentin and bone. Apart from type I collagen being the leading extracellular matrix element, other common proteins and proteoglycans are osteonectin/SPARC, osteocalcin, osteopontin, bone sialoprotein, decorin and biglycan [33].

Dentin proteoglycans plays a key role in mineralization of the dentin and bone, so they perform structural, metabolic, and functional role. The proteoglycans are classified as small leucine-rich proteoglycans (SLRP) and the large aggregating proteoglycans. The SLRP are further divided into 5 classes: decorin; biglycan; fibromodulin; lumican and osteoadherin. Among the large aggregating proteoglycan is only versican has been described well in dentin [25].

Osteocalcin and osteonectin are classified under secretory calcium-binding phosphoprotein a category of non-collagenous proteins. Osteocalcin is a vitamin K-dependent gamma-carboxylated protein. It is a small calcium binding protein consisting of three glutamic acid residues. It is found in dentin in small amounts as compared to the bone [25]. Osteonectin binds collagen, hydroxyapatite and growth factors. It is known to regulate proliferation of cells, prompts angiogenesis and formulation of matrix metalloproteinases [34]. Another subset of the secretory calcium binding phosphoprotein is the Small Integrin-Binding ligand, N-linked Glycoprotein (SIBLING) family. It includes osteopontin, bone sialoprotein, dentin matrix protein 1, dentin sialophosphoprotein, and matrix extracellular phosphoglycoprotein [35].

Dentin phosphoprotein (DPP) and dentin sialoprotein (DSP) were earlier thought to be unique to dentin [5, 33]. Later some immunohistochemical studies established that DSP is also present in the alveolar bone, cellular cementum, osteocytes, cementocytes and their matrices [36]. DPP is rich in aspartic acid and phosphoserine and bind calcium in considerable amounts. DSP is a glycoprotein rich in aspartic acid, serine, glutamic acid, and glycine. Both DPP and DSP are synthesized by odontoblasts and pre-ameloblast cell types. In contrast the bone matrix proteins are not exclusively made by the osteoblasts. This makes dentin unusual based on these dentin specific proteins [33]. DSP has been shown to play a role in prompting differentiation of dental pulp cells in odontoblast-like cells [36].

3.2 Dentin growth factors

Growth factors are natural activation signals or substances able to stimulate cellular proliferation, wound healing, and sometimes cellular differentiation. Generally, a growth factor is secreted protein or a steroid hormone [37, 38]. They are necessary for regulating various cellular processes that take part in tissue regeneration procedure [39, 40].

Growth factors are generally acting as signaling molecules between the cells, like cytokines and hormones binding to specific receptors on the target cells surfaces. Examples of growth factors in dentin are TGF- β group, BMP group, Insulin growth factor-1, hepatocyte growth factor, VEGF, Adrenomedullin, FGF-2, platelet-derived growth factor, growth/differentiation factor etc. a summary of these growth factors is given in **Table 1**.

We can group these growth factors by their actions as: Angiogenisis (FGF-2, PDGF, VEGF, NGF); Differentiation (TGF-β, PDGF, FGF-2, BMPs, IGF, NGF); Proliferation (PDGF, FGF-2, IGF, VEGF, TGF-β, SDF-1); Chemotaxis (PDGF, FGF-2, TGF-β, SDF-1) and Neuronal growth (NGF) [41].

Transforming growth factor-beta	
TGF-β1	Promoting tertiary dentinogenesis and in primary odontoblastic differentiation.
TGF-β2	Upregulated on DPSCs differentiation into a mineralizing phenotype
TGF-β3	Promotes odontoblastic differentiation
Bone morphogenetic proteins	
BMP-2	Promotes vitro and in vivo odontoblastic differentiation, DSPP induction and increases alkaline phosphatase activity
BMP-4	Increases odontoblastic differentiation
BMP-7	Promotes DPSCs phenotype mineralization
Insulin growth factor-1	Promotes proliferation and differentiation of DPSCs and SCAP into a mineralizing phenotype
fibroblast growth factor 2 (FGF-2)	Promotes stem cell homing (chemotaxis), angiogenesis, and stemness
Platelet-derived growth factor	Promotes angiogenesis, chemotaxis of MSCs modulates the process of odontoblastic differentiation, synergistic act with other growth factors
Growth/differentiation factor 15	Promotes axonal function and regeneration after injury and plays important role in neuronal maintenance
Vascular endothelial growth factor VEGF	Potent angiogenic factor that promotes blood vessel formation in tooth slices implanted subcutaneously in SCID mice
Hepatocyte growth factor	Promotes survival, proliferation, and migration of MSCs
Adrenomedullin	Promotes odontoblastic differentiation through activation of p38
Epidermal growth factor	Enhances neurogenic differentiation of DPSCs and SCAP
Placenta growth factor	Promotes osteogenic and angiogenesis differentiation of MSCs
Brain-derived neurotrophic factor	Promotes neuronal growth and axonal targeting
Glial cell line-derived neurotrophic factor	Promotes in vivo nerve regeneration and pulp cell proliferation. Increased expression during odontogenic differentiation.

Table 1.
Growth factors in dentin matrix and their role.

The growth factors diffusion into the dentinal-pulpal junction is postulated to activate reactionary dentinogenesis and simultaneous reparative dentinogenesis along with pulp tissue inflammatory reaction [42, 43]. The surviving odontoblasts secrete reactionary dentin as a response to environmental stimuli causing metabolic activity increase in the cells. The inductive molecules determining the success of the pulp healing might be released from damaged dentin and adjacent pulp tissue [44]. Dentin-pulp regeneration process can vary as it depends on the causative agent whether trauma or pathological conditions. An inflammatory reaction is caused by these events, which is supposed to be the beginning of tissue regeneration process [39]. Dentin-pulp defensive and reparative mechanisms mimic the embryonic tooth development stage and growth factors derived from dentin may play a key role in regulating these events [42]. The dentinal matrix constitutes angiogenic growth factors and their release after injury can contribute to overall reparative response of the dentinal-pulpal complex [45].

There are multiple growth factors in dentin that also exist in bone like insulin-like growth factor-1 (IGF-1), insulin-like growth factor-2 (IGF-2), transforming growth factor-beta (TGF-β), fibroblast growth factors (FGFs), platelet-derived growth factor (PDGF), parathyroid bone morphogenetic proteins (BMPs), and certain members of the growth differentiation factor (GDF) group of proteins [46–48]. That is why recent studies have shown good results after using dentin as a bone graft and stated that dentin has shown to be clinically safe and has good bone-forming capacity [49, 50].

Also known as autogenous tooth biomaterial it is derived from an extracted tooth through demineralization process. It is useful as graft material because of its osteoconductive properties [51]. This biomaterial can be used alone or combined with other materials for example with platelet-rich fibrin [52], bone marrow mesenchymal stem cells [53] or bone morphogenetic protein (BMP-2) [54] for enhanced bone regeneration effects. Recently a dentin derived barrier membrane acting as an osteoinductive collagen membrane showed successful outcome in guided bone regeneration and dental implantation. The membrane was derived from block type autogenous demineralized dentin matrix with advantage of overcoming the mechanical instability of the collagen membrane. It is mostly composed of type I collagen, making it suitable for use in implant procedures [55].

4. Dental defects

Enamel has 3 essential enamel proteins to build healthy well mineralized enamel which is secreted from ameloblasts "amelogenin, ameloblastin and enamelin" with the help of two enzymes, MMP20 and kallikrein-4 (Klk4) to form the enamel properly and sequent proteolysis of enamel protein [56]. In the event of alteration in the process of protein removal, enamel and dental defects will emerge like for example, amelogenesis imperfecta (AI), Chalky/Molar Hypomolarization (MH), Dentinogenesis Imperfecta (DI) or fluorosis [57]. **Figure 3** depicts the protein content in healthy and diseased tooth.

4.1 Amelogenesis imperfecta (AI)

Amelogenesis imperfecta is a rare, inherited enamel development disorder where mutations in the amelogenin gene results in malformation of the enamel layer. It is subdivided to 4 main types hypoplastic (type I), hypomaturation (type II), hypocalcified (type III), hypomaturation/hypoplasia/taurodontism (type IV).

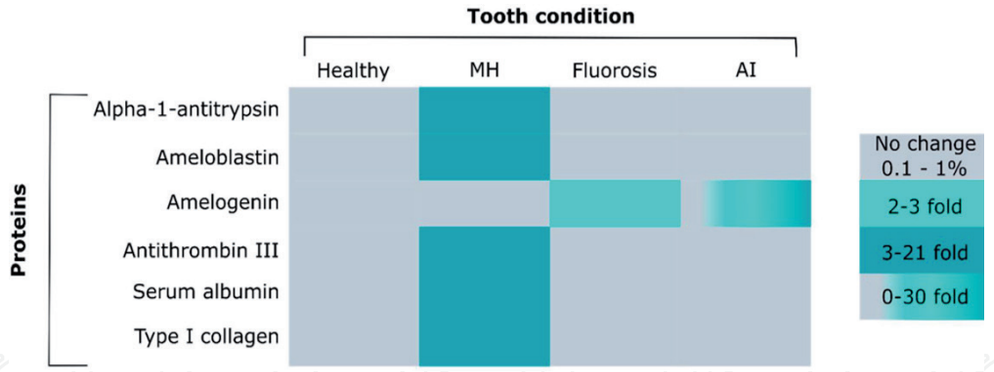

Figure 3.
Protein content is compared between healthy and diseased tooth enamel. Different proteins are presented in (rows) as analyzed different tooth conditions (columns). Healthy teeth is presented as reference in light gray, chalky/molar Hypomolarization (MH): Enamel affected by molar hypomineralization, fluorosis and Amelogenesis imperfecta (AI): Hypocalcified and hypomaturation amelogenesis imperfecta enamel; range of percent by weight (wt %) of protein abundance in comparison to healthy enamel show in 4 colors: Healthy range of 0.1–1 wt % (light gray); 2–3 times increase (light teal); 3–30 times increase (dark teal); 0–30 times increase (gray-teal gradient) [57]. Figure adapted from Gil-Bona a et al. (2020).

Clinical and radiographical features and enamel thickness, of different subtypes are dependent on mode of inheritance and gene mutation. AI occurs due to mutations in several genes, including enamelin, amelogenin, MMP20, Klk4 and FAM83H [58–61]. The mutations can lead to hypoplastic, hypomature, or hypocalcified form of the enamel [62]. AI can be easily seen clinically and radiographically as teeth appears in abnormal color like (yellow, brown, or gray). Soft enamel, due to hypo calcification enamel surface are more susceptible to caries, tooth attrition, teeth hypersensitivity, calculus formation, and gingivitis/periodontitis [63].

Type I hypoplastic AI has reduced thickness of enamel and shows pitting and grooves. In radiographs enamel shows normal contrasts from dentine. Type II hypomaturation AI has enamel of normal thickness but appearance is mottled. It is less severe than hypocalcified type. Radiographically it exhibits similar radiodensity as dentine. Type III hypocalcified AI have defect in enamel calcification. The enamel thickness is normal but is weak in structure and appearance is opaque and chalky. In radiographs enamel is less radio-opaque in comparison to dentin. Type IV hypomaturation/hypoplasia/taurodontism AI exhibits mixed hypomaturation and hypoplasia appearance. In taurodontism enlargement of the body and pulp chamber is observed. The pulp chamber floor and furcation moves apically down the root [58].

A proper diagnosis identifying the different phenotypes is essential to determine molecular etiology. The treatment plan aims at early diagnosis, managing the pain and restoring the defects with regular follow ups [58]. Mild variations can be treated adequately with facial veneers, whereas in severe cases full coverage is mandatory. For young patients milled acetal resin overlays can be used until fully erupted [64].

4.2 Chalky/molar hypomineralrisation (MH)

It is discolored white patches in one or more molars, porous dental enamel leads to hypersensitivity and risk of caries. Chalky enamel opacities contained unusually high amounts of protein, including serum albumin and other derivatives of blood and saliva [65]. Moderate and severe cases with opacities having a chalky texture exhibit failure of enamel surface soon after the eruption of tooth, it provides a hygiene-resistant nidus for dental plaque accumulation. The porous chalky enamel is invaded by accelerated decay which arises the need for restoration, extraction, or

orthodontic treatment. It is observed that MH affects the 2-year molars or 6-year molars, a better understanding of its etiology is necessary [66]. Earlier systemic disturbance of enamel-forming cells (ameloblasts) during the hardening (maturation) stage of enamel formation was thought to be the cause [67]. A different pathomechanism indicating localized exposure of enamel to serum albumin was recently identified [68]. In a recent study the dose–response relationship between albumin and the enamel chalkiness was established. This supports the new pathomechanism also termed as "mineralization poisoning" [66].

MH is a complex problem requiring combinational treatment modalities. The treatment aim may be preventive or symptom control. Various treatment modalities can be adhesive and sealant restoration, composite restoration, glass ionomer restoration, preformed metal crown, microabrasion, bleach or orthodontic extraction [69].

4.3 Fluorosis

Dental fluorosis is a very common developmental disturbance that is caused by repeated exposures to high concentrations of fluoride during tooth or enamel formation. This leads to disturbance in enamel formation as the fluoride decreases calcium concentration in the matrix. This interferes with protease activity and delays or inhibit enamel matrix protein degradation. An abnormal apatite crystals growth occurs which leads to physical tooth surface changes [70]. It differs from white striations to stained pitting of the enamel depending on case severity [71]. The use of topical fluoride dentifrices in young children may increase the risk of dental fluorosis. In case of concern for fluorosis, in children under 6 years of age toothpaste with fluoride concentration less than 1000 parts per million should be used [70].

Treatment of the case depends on the severity and the esthetics concerns. Mild cases can be treated by bleaching if the tooth. For moderate cases enamel microabrasion with acids can be done. Composite fillings, veneers and crowns can be used for treating cases with severe forms of the disease [72].

The best solution for this condition is to control the fluoride intake for prevention of dental fluorosis [71].

4.4 Dentinogenesis imperfecta (DI)

DI is also an inherited condition also called "dentin dysplasia" with discolored teeth but most often blue-gray or yellow-brown which leads to wear, breakage, and loss of teeth. This damage can include teeth fractures or small holes (pitting) in the enamel. The enamel may have hypoplastic or hypocalcified defect in nearly one-third of patients and has tendency to crack away from defective dentin. It is a localized mesodermal dysplasia which affects both primary and permanent dentition. It is inherited in simple autosomal dominant mode exhibiting high penetrance and low mutation rate [73].

DI has 3 types: Type I: occurs in people who have osteogenesis imperfecta so, it appears to have other health concern (mutation in COL1A1/A2 gene). Type II: the most common type occurs in people without another inherited disorder (mutation in DSPP). Radiographically it shows complete obliteration of the pulp cavity by dentin. Type II and type III, are actually similar conditions but in different forms but DI type III shows enlarged pulp cavities [63].

In histological findings although enamel is normal in structure it tends to crack. Scalloping is absent in dentino-enamel junction. Mostly mantle dentin structure is normal. However dentinal tubules of the circumferential dentin are found to

be coarse and branched. The tubules are reduced in quantity. An atubular area is present in the dentin with reduction in mineralization and decreased number of odontoblasts. Another common finding is pulpal inclusions and much interglobular dentin [73].

Treatment differs from case to case depend on its severity and presenting pain, also the patient age. Mostly treatments are targeted at maintaining oral hygiene and esthetics. Early diagnosis and treatment can prevent deterioration of teeth and occlusion. In severe cases two treatment stages for primary teeth under general anesthesia is recommended. At the age of 18-20 months the stage 1 treatment involves composite restorations covering for incisors and preformed crowns for first primary molars. At the age of 28-30 months stage 2 aims at protecting second primary molars and canines. For moderate cases one-stage treatment for primary teeth at 30 months of age is optimal. In severe cases composite restoration may not be helpful. A long term follow-up is necessary to adjust treatment according to change in dentition and occlusion [73].

5. Conclusion

The enamel and dentin organic content varies in amount and its constituents. The enamel proteins help in imparting the elastic and visco-elastic properties to the enamel. The clinical significance of the non-collagenous proteins may be in relation with dentinal growth factor release by calcium hydroxide or mineral trioxide aggregate. The dentin organic matrix constitutes similarity with that of bone, makes it a desirable bone graft material. Demineralized dentin autogenous bone grafts have already been used for dental implant surgeries and provides an easy to prepare and use bone graft material. Any imbalance in the organic content can manifest as developmental disease of the tooth.

Conflict of interest

The authors declare no conflict of interest.

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