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Morphological and Chemical Analysis of Dentin and Enamel Layers of Eroded Deciduous Tooth: from Imaging to Understanding

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Abstract – Deciduous teeth are much more sensitive to wear and erosion due to their thin enamel layers. Especially in children, when there are structural jaw problems, dietary habits become very vulnerable to erosion of the teeth. In this study, morphological analysis of the deciduous tooth was made with 2D and 3D SEM studies, and the tooth's erosion was examined. In particular, the formation and development of pits were determined and defined. Both enamel and dentin layers were chemically examined separately, and it was shown that the enamel level was richer in PO_4. As a result, it has been shown that multifactorial effects erode the tooth.

Keywords – Deciduous, SEM analysis, Abrasion, Corrosion, Enamel and Dental Chemistry.

I. Introduction

Pathodynamic mechanisms of the tooth surface lesions are classified as attrition, abrasion, erosion, and abfraction, and they are all related to friction, corrosion, and stress [1]. Abrasion corresponds to the mechanical process involving foreign objects or substances, while attrition happens due to tooth-to-tooth contact [2] . Besides, Imfeld [2] also adds that the chemical etching and dissolution cause erosion. This latter can be called corrosion. Since these terms do not fully reflect the developing pathodynamics, terms such as abfraction for non-carious lesions and corrosion for decompositions by chemical action have begun to be used, but uncertainties still remain [1, 2, 3]. Repetitive and concomitant abrasion and attrition effects are more common mechanical effects, especially on deciduous teeth [5]. Besides, it has been known for a long time that dietary acids have an erosion effect on tooth enamel [6, 7, 8] . The most frequently consumed erosive acids are fruit acids and phosphoric acid in fresh fruits, fruit juices, and soft drinks [2].

A crown made of highly mineralized and protective enamel caps the dentin layer [9]. In this study, a crown exhibiting the lesions caused by mechanical and chemical effects on a deciduous tooth was examined at the microscopic level. Structural and morphological analyzes were made in the eroded areas in 2D and 3D, and the chemical differences between the enamel and dentin layers were revealed.

II. Materials And Methods

In this study, the crown part of a molar deciduous tooth was examined from both the upper (enamel layer) and the inner sides (dentin layer). The tooth belongs to a passion who suffered an underbite and was corrected by prolonged treatment. The crown is first placed on a carbon stub and coated with carbon in high vacuum-high voltage to ensure surface conductivity for the electrons. We reported chemical analysis of dentin and enamel layers using Quantax 500 Silicon Drift Detector mounted on ZEISS EVO-50 EDX-SEM at Hacettepe University in Ankara, Turkey, with operating conditions of 15 kV acceleration voltage, 12 nA beam current, 10 s live time counting, and ZAF correction. Then, both the crown's upper and inner levels were imaged in 2D and 3D. Alicona-MeX 5.1. software was used to obtain the 3D images. First, the outline of the crown on constituted 3D images was drawn as a polygon, and later, all textural descriptors such as roughness parameters, profile analyses, and all statistical surface parameters were calculated, conforming to the International Standards of EN ISO 4287/4288.

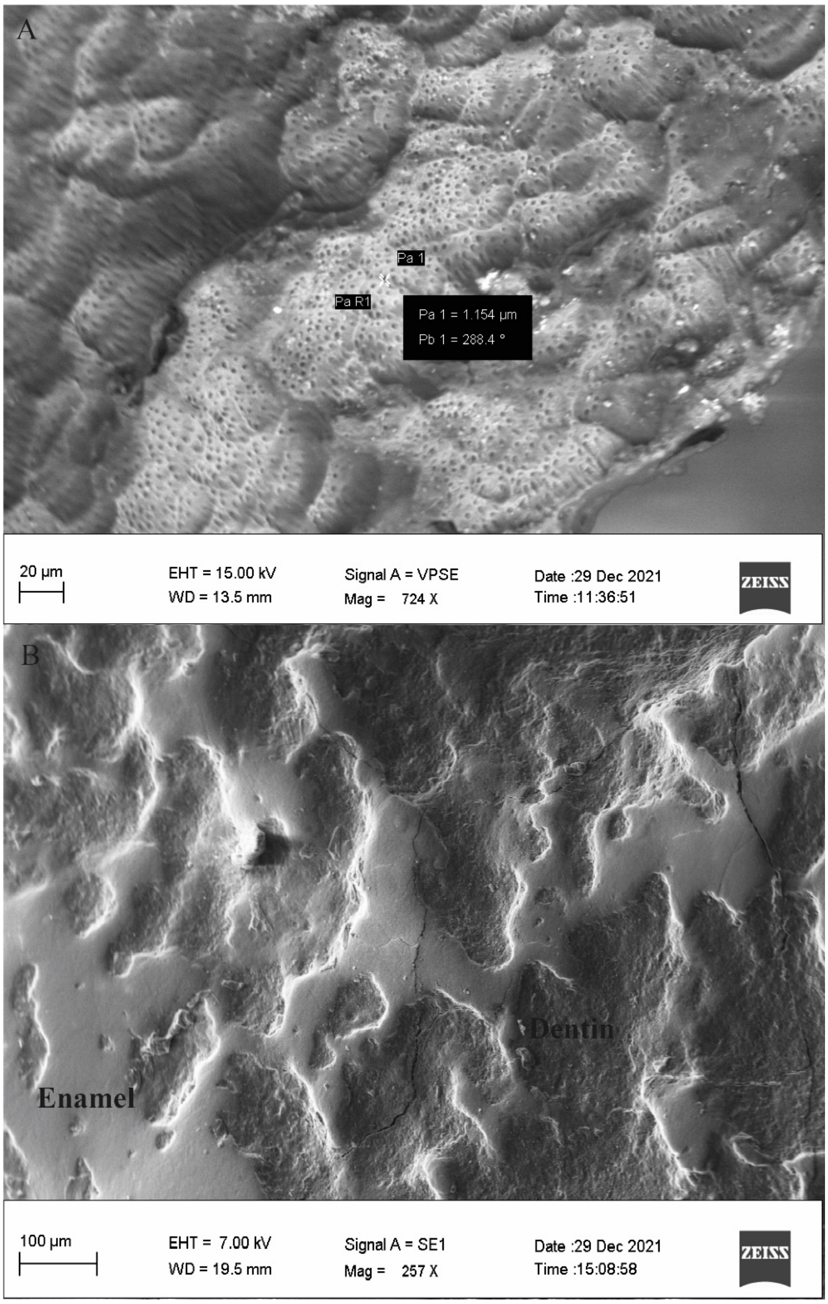

Figure 1. 2D SEM Images.

A. Globular dentin layer of the crown (inner part). Tubules are open and their diameter reachs to 1 micron.

B. Upper part of the crown with eroded Enamel layer. Dentin layer appears at the base.

III. Results

3.1. Electron Microscope Visualisation:

We performed 2D and 3D Electron Microscope studies from the upper and inner parts of the crown (Fig.1). The inner level consists of globular dentin (Fig.1A). Tubules are open, and their diameter is usually 1 micron and smaller. Globules are irregular and heterogeneous. The outer part of the crown has too many rough surfaces, and we see that the enamel layer is worn on the surface and the dentin layer appears from the bottom (Fig.1B). The removal of this top layer does not have sharp boundaries, and intricate boundary relationships are observed.

3-dimensional illustration of the crown upper part clearly shows the erosions with circular lesions in an 8x7mm sized reconstructed image (Fig2A and B). The crack must have happened after the extraction. Tiny pits resemble

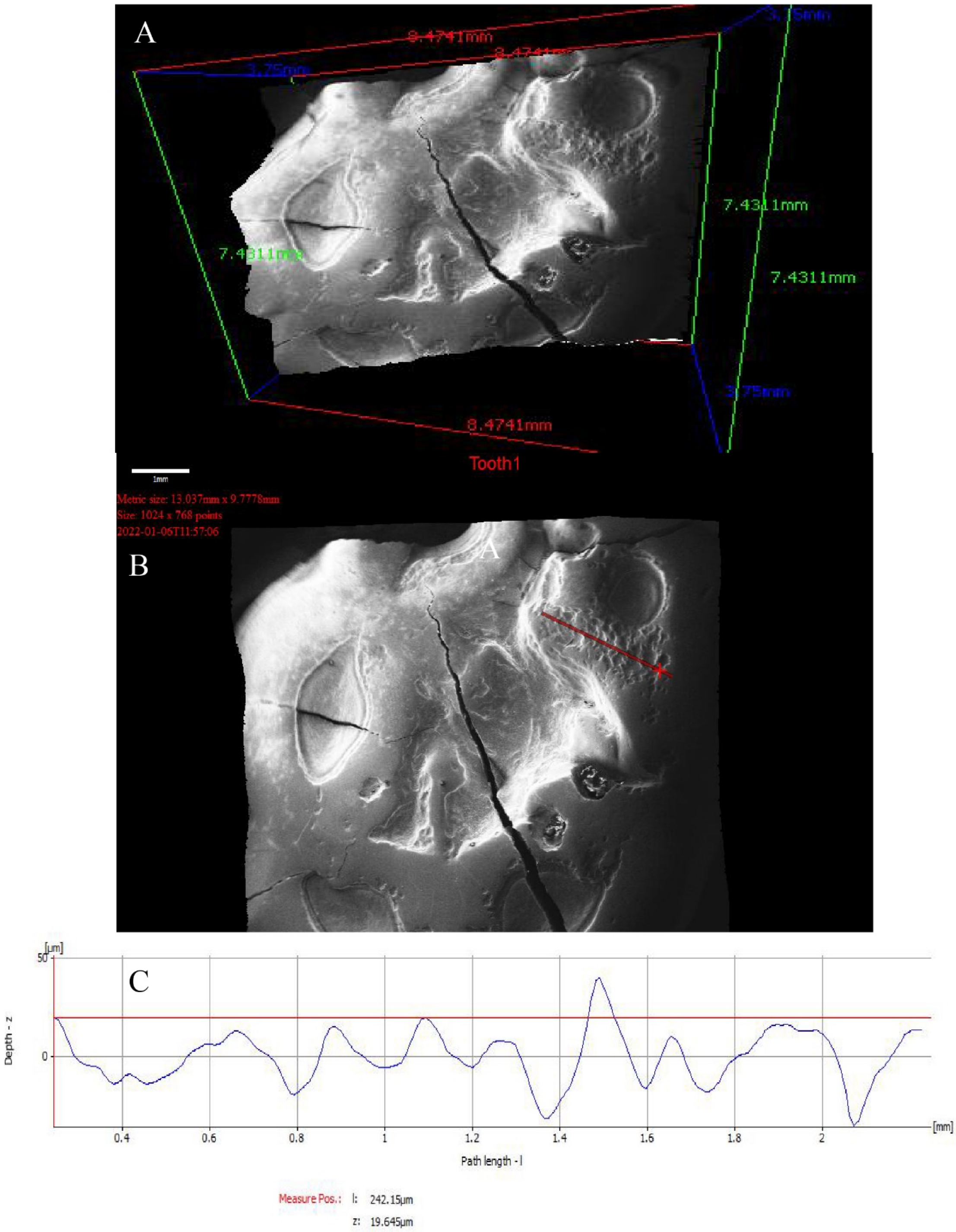

Figure 2. A. 3D illustration of the upper part of the crown. The Picture is reconstructed with Alicona Mex software.

B. 3D illustration with analysed profile (red line)

C. Roughness profile across the erosion pits along the profile

Multiple dissolutions etch pits on the upper right side. It is observed that small depressions have coalesced over the tooth. The red line in this area corresponds to the line of the 3D profile analysis we did along the line. Profile roughness is given in Fig2C, and calculated profile parameters are presented in table1. It is observed in Fig2C that the pits have the form of a tapering cone,

Table 1. Calculated statistical parameters along roughness profile presented in Figure 2C.

Name	Value	Description
Ra	10.688µm	Average roughness of profile
Rq	13.349µm	Root-Mean-Square roughness of profile
Rt	76.075µm	Maximum peak to valley height of roughness profile
Rz	46.063µm	Mean peak to valley height of roughness profile
Rmax	57.96µm	Maximum peak to valley height of roughness profile within sampling length
Rp	39.824µm	Maximum peak height of roughness profile
Rv	36.251µm	Maximum valley height of roughness profile
Rc	41.558µm	Mean height of profile irregularities of roughness profile
Rsm	311.56µm	Mean spacing of profile irregularities of roughness profile
Rsk	-0.1572	Skewness of roughness profile
Rku	32.242	Kurtosis of roughness profile
Rdq	0.3853	Root-Mean-Square slope of roughness profile

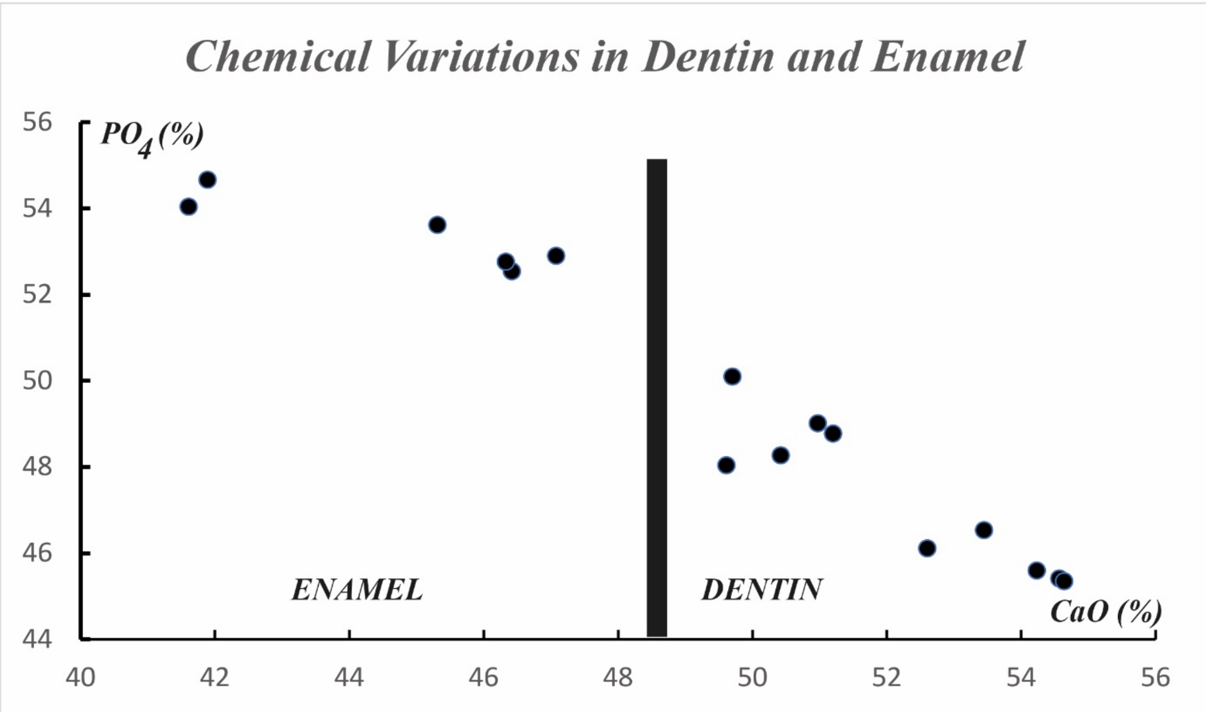

Figure 3. Chemical variations in Dentin and Enamel Layers. Black line doesn't correspond to chemical limit but the appropriate place of dentinoenamel junction

and they are all at different depths. While there is a difference of 76 microns between the deepest point and the highest point (Max peak to valley height), the deepest trough is 36 microns, and the highest peak is approximately 40 microns. The overall profile is very rough.

3.2.Chemical analysis:

In the study, enamel and dentin chemistry and changes were carried out quantitatively and qualitatively, by point analyzes (Fig.3), "Line Scan" (LS) analyzes showing composition changes along a line, and also in the form of X-Ray Maps (Fig.4). Point and LS chemical analyses on enamel and dentin show that it is composed of varying amounts of CaO, PO_4, Na_2O, and MgO as (inorganic) chemical composition. It is observed that the PO_4 content is high at the enamel level that is not yet eroded or slightly exposed on the upper surface of the crown, and the CaO content is higher in the analyzes taken from the dentin level. In addition, a gradual chemical transition between enamel and dentin was observed at points with different amounts of eroded. In Fig4A and B, the Dentinoenamel junction is illustrated. We see a Ca enrichment on this junction. Enamel is riched by P while Ca increase toward the dentin. This is also proved by LS Profil chemical analysis (Fig4C).

IV. DISCUSSION

Tooth wear can be divided into different types according to morphological and etiological factors [10]. Therefore, SEM works are widespread in dental research and characterize the types of lesions with specific morphologies and mechanisms [10].

Deciduous teeth are slightly different from permanent teeth anatomically [5]. The enamel of the deciduous teeth is thinner than that of the permanent ones [5]. Thin enamel will naturally wear faster, and erosion and corrosion can be much more effective.

Tooth erosion may occur by removing chemically abraded dental hard tissues from the tooth surface with acids [11]. The beverages like fruit juices, soda, snacks, sugar can profoundly affect the tooth enamel. Continuous exposure to acids provokes dental erosion [12].

In our case, the deciduous tooth was observed to be highly eroded. Especially in dental enamel, there are many dissolution pits, and we think that such intense wear cannot only be caused by mechanical means, namely abrasion, and attrition, and acids must also have a significant effect. In particular, the roughness profile shows conical erosion, and these patterns coalesce and coalesce as erosion continues. While it was clearly observed that the pit was widened, especially on the right head, small holes were seen on the other sides of the profile.

While 2D SEM studies are widely used in clinical research, 3D is used relatively less. Recently, x-Ray Microtomography and SEM studies for 3D have started to be combined [13]. In our study, 3D roughness analysis allowed us to describe the erosional pit patterns and morphology of the corrosion structure.

The combined and multifactorial effects of the pathodynamic mechanism on tooth enamel have been previously demonstrated in Grippo et al [1]. Therefore, we believe that such kinds of combined or multifactorial effects happened in our case.

The minerals in enamel and dentine are imperfect forms of calcium phosphate hydroxyapatite: $Ca_{10}(PO_4)6(OH)_2$[14]. Our quantitative and qualitative chemical analyses show that the enamel layer is richer in PO_4 as expected. It is important to quote that a tooth can form dominantly from inorganic substances, but important organics are also present. What we present here in this study, we only analyzed the inorganic components. We clearly demonstrated a chemical difference between the enamel and dentin layers.

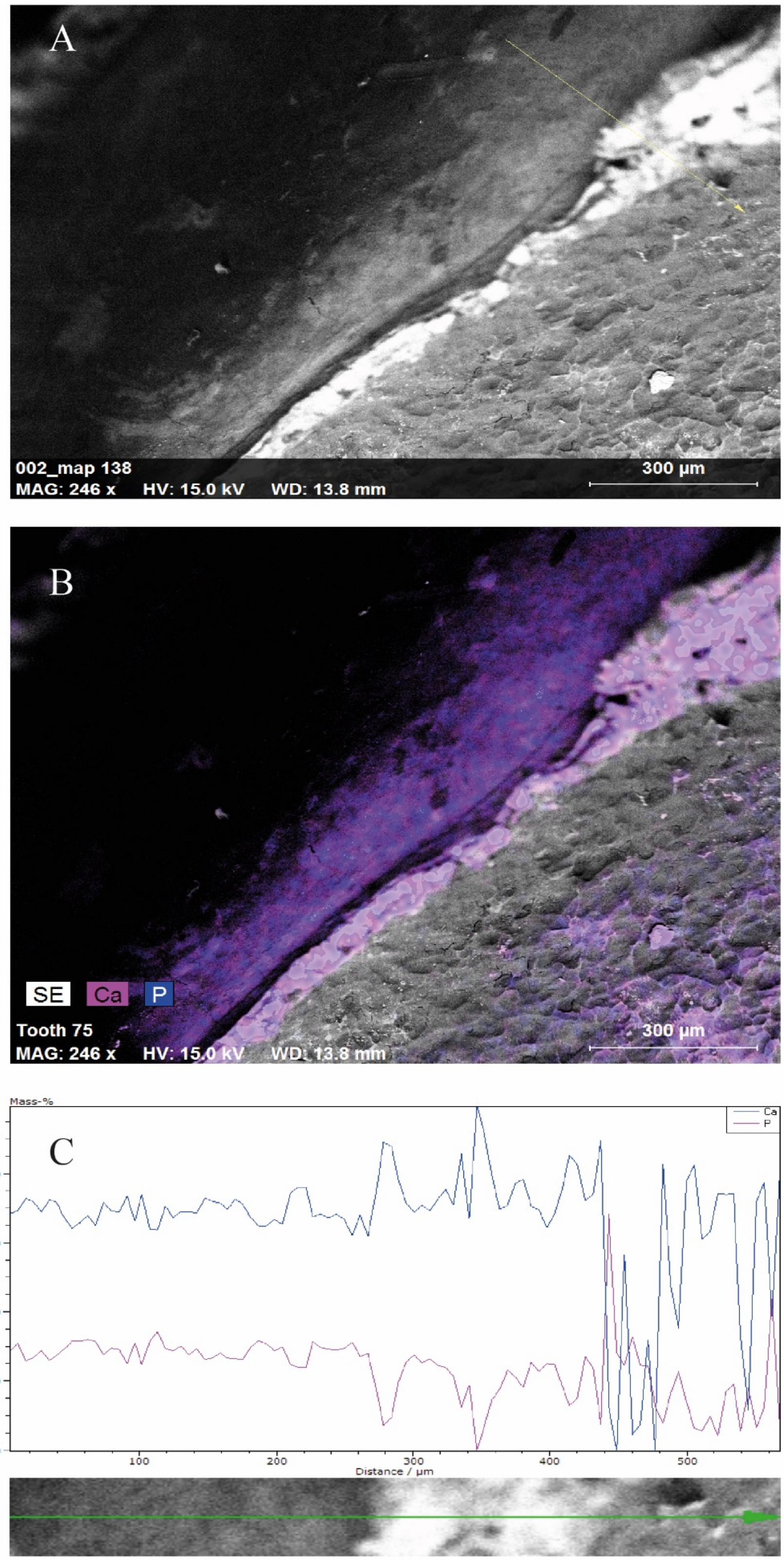

Figure 4. A. SEM image of Enamel and Dentin layers with Dentinoenamel junction. Yellow arrow is the Line Scan trajectory

B.X-Ray Map of same image presented in Figure 4A.

C. Line Scan Chemical Analysis along yellow arrow presented in Figure 4A.

V. Conclusion

High-resolution SEM imaging is an extremely important topic in dental research. Especially when we carry SEM studies to the 3D dimension, it is possible to make morphometric analysis. For example, our morphological analysis determined that abrasion, attrition, abfraction, and corrosion in a child's deciduous tooth with an underbite jaw structure developed sequentially, and these processes developed continuously, not in a single order but as multifactorial.

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