Enamel microstructure of deciduous teeth:
Types of enamel and resistance to abrasion.

Tanevitch, Andrea
Durso, Graciela
Batista, Susana
Abal, Adrián
Llompart, Gabriela
Llompart, Jorge
Martínez, Cristina
Licata, Lila

atanevitch@gmail.com

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* Facultad de Odontología UNLP - Cátedra de Histología y Embriología

INTRODUCTION

The study of the histological structure of enamel can be approached in different ways. One of them allows to establish functional morphological studies, ontogenic or phylogenetic adaptations and/or restrictions (Koenigswald, Goin 2000; Goin et al. 2007) by applying a hierarchical system of classification of tooth enamel microstructure in mammals considering the complexity levels proposed by Koenigswald and Clemens (1992). Five levels can be observed:

1) crystallites: this is the simplest level and studies the smallest of these units, the morphology and the packing of crystal patterns in a small area;
2) prisms: this level includes the description of prismatic and non-prismatic enamels considering their morphology and interprismatic substance;
3) enamel types: this level refers to prismatic enamel types;
4) enamel patterns (schmelzmusters): this level refers to the three-dimensional arrangement of the different enamel types in a tooth and has shown to be relatively constant in some mammalian families and subject to small individual variations;
5) dentition: this level provides significant data for the study of the evolutive relations at specific or generic level (Koenigswald and Clemens 1992; Koenigswald, Sander 1997). This classification, not used in the dentistry field yet, allows to incorporate the concept of enamel types, not as mere structures, but as specific designs destined to fulfill specific functions (Goin 2007).

Enamel types are organized in layers separated by clearly defined boundaries. Within each layer prisms present similar morphology, orientations and packing. The different enamel types are the following: radial enamel, modified radial enamel, tangential enamel, vertical and horizontal Hunter-Schreger bands (HSB), irregular enamel, 3D enamel (Koenigswald, Sander 1997).

Studies done on human permanent pieces showed the presence of radial enamel, enamel with bands and irregular enamel (Durso et al. 2008), whose distribution depends on the dental occlusion and masticatory functions .

One of the forces to which enamel is exposed is abrasion or wearing. Loss of enamel as consequence of these factors is irrecoverable and occurs in both permanent and deciduous teeth. There exist two phylogenetic solutions to this problem:

a) continuous tooth replacement, as occurring in many reptile groups, and
b) specialization at tissue microstructural level (Rensberger 1997).

Resistance to abrasion can be considered in terms of hardness. Enamel hardness represents the resistance of the surface to scratching deformations caused by different forces. It is a physical property that depends on different factors and decreases from the free surface to the dentin-enamel junction. The type of wear in mammalian enamel is strongly influenced by prism orientation [Rensberger 1997].

Prisms tend to remain arranged in rows that circle the tooth main axis. Longitudinally oriented, a prism does not follow a straight pathway through enamel thickness but acquires a half spiral shape with some intercrossing at some points. Maas [1991], after studying enamel microstructure in relation to microwear, considers that the different responses of prismatic and non-prismatic enamels to abrasion reflect the influence of structure, but at the level of organization of crystallites rather than at the level of prisms.

Jiang [2003] highlights that prism intercrossing provides a mechanism to prevent fracture propagation and enhances resistance to tensile forces.

The purpose of this work was to study the arrangement of enamel types and resistance to abrasion in deciduous teeth.

OBJECTIVES

To identify the arrangement of enamel types in anterior deciduous teeth.
To determine Vickers hardness values in different enamel zones of anterior deciduous teeth.

To relate enamel microstructure (in the enamel types level) and resistance to abrasion of human deciduous incisives.

MATERIALS AND METHODS

Six temporary incisive and canine crowns with intact and healthy enamel were exfoliated or extracted as indicated. They were acrylic resin embedded forming a block that allowed crown wear on one plane. They were worn in a bucco-palatine direction and final shine polishing was done. They were etched in 10% hydrochloric acid for 2" or 3" to expose enamel microstructure, ultrasonically washed and dried. No metallization was done and they were observed under Environmental Scanning Electron Microscopy (ESEM FEI Quanta 200). Micrographs were registered in the cervical, medial and incisal thirds.

Hardness was determined using microdurometer belonging to the LIMF metallographic laboratory, Vickers penetrators, 10-gr loads, and application time of 10 seconds, in the inner and outer zones of the enamel of the medial and incisal thirds. Statistical analysis was performed by means of t-test and the value of significance was set at $p<0.05$.

RESULTS

TYPES OF ENAMEL

In deciduous anterior teeth, in the enamel type level, radial enamel was found in the outer zone and enamel with bands (HSB) was found in the inner zone, each with variable thickness both in the medial and incisal thirds (Figure 1). Enamel with Hunter-Schreger bands is seen to occupy 238.84 µm of the enamel inner thickness and radial enamel is seen in the outer zone. ESEMx352 (Figure 2). *Enamel with Hunter-Schreger bands is seen to occupy 444.51µm of the enamel inner thickness and radial enamel is seen in the outer zone. ESEMx352. In the cervical third radial enamel was observed* (Figura 3). Enamel belongs to the radial type. ESEMx349.

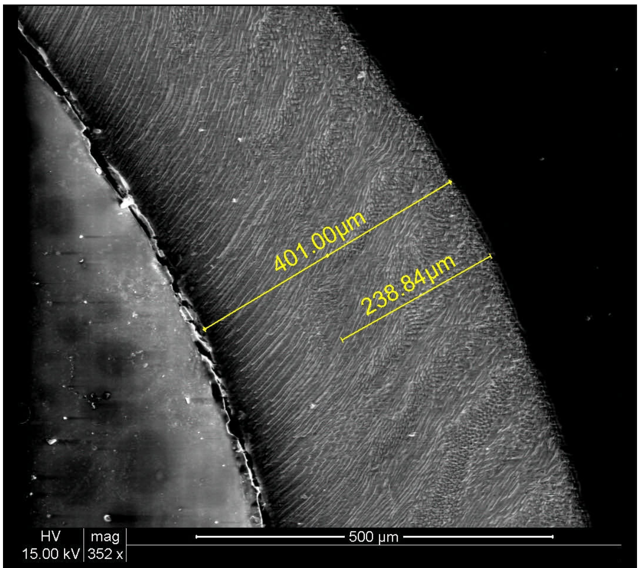

Figure 1
Electron micrograph of deciduous enamel in the medial zone of the free faces.

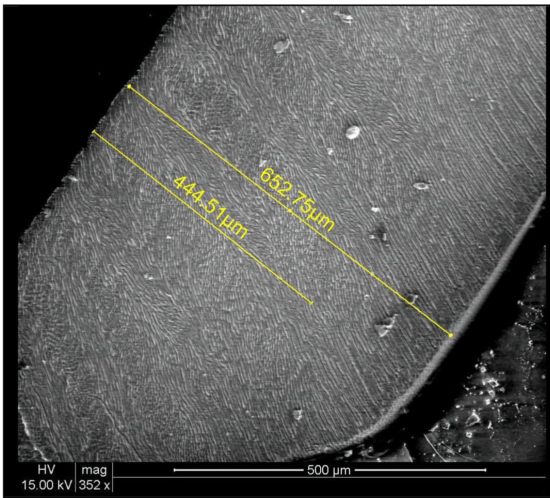

Figure 2
Electron micrograph of deciduous enamel in the incisal zone of the free faces

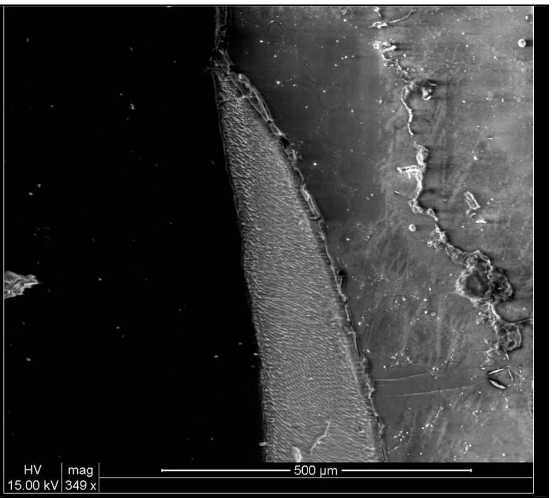

Figure 3
Electron micrograph of deciduous enamel in the cervical zone of the free faces

In the radial enamel axial axes of prisms are parallel one to another starting at the amelodentinal boundary and towards the outer surface of the tooth; while in the enamel with HS bands prisms intercross in layers and present concordant orientation changes in their pathway through the amelodentinal boundary as far as the enamel outer surface. Prisms of adjacent bands show opposite orientations thus producing decussations (intercrossings).

MICROHARDNESS VALUES

Twelve hardness registers were obtained and it was found that in the inner zone (HSB enamel) the register was HV_{10}= 251.158 VK (SD= 27.257) and in the outer zone (radial enamel) it was HV_{10}= 351.475 VK (SD=63.846). T-test was performed and difference was found to be significant (p=0,000).

Twelve hardness registers were obtained in the medial and incisal thirds showing the following values: enamel in the medial third HV_{10}= 395.200 VK (SD= 40.096) and enamel in the incisal third HV_{10}= 404.083 (SD=45.092). Difference was not found to be significant (p=0.615).

DISCUSSION

Studies by Meredith et al.[(1996)] evidenced that enamel hardness decreased as its depth increased starting from the external surface.

These variations are possibly caused by changes in the local chemical composition, in microstructure and in prism orientation [(Braly 2007)].

Significant difference was found in Vickers hardness between the outer and inner zone of enamel in temporary teeth, this being higher in the former. As regards microstructure, we observed different types of enamel in temporary anterior teeth. Radial enamel was found on the outer surface of the enamel and enamel with bands (HSB) was found on the inner surface.

These variations in enamel microstructure would be related to the variations in hardness values.

Boyde A, Fortelius M. [(1986)] concluded that the most important factor in resistance to enamel abrasion is the orientation of the prism axis with respect to the occlusal surface. Enamel prisms that are perpendicular to the masticatory surface are more resistant to abrasion.

If we consider resistance to abrasion in terms of hardness, radial enamel is the most resistant one.

Xu HH et al. [(1998)] hold that fracture propagation can be influenced by enamel prisms and the amelodentinal boundary. Results showed that fractures in the axial sections of enamel were significantly longer in the perpendicular orientation towards the occlusal surface than in the parallel one. They concluded that the mechanical properties of teeth depend on the microstructural orientation.

Radial enamel, although presenting Vickers hardness values higher than in HSB enamel, would facilitate fracture or crack propagation towards the inner zone of the adamantine tissue.

Lynch et al. [(2011)] state that enamel tends to cleavage along the prism rows. However, prism group undulations become evident as Hunter-Schreger bands that prevent the progress of fractures.

Hunter-Schreger band enamel constitutes an enamel microspecialization to prevent or stop fractures. However, lower hardness values make enamel less resistant to abrasion.

CONCLUSION

Radial enamel possesses better resistance to abrasion, thus it records higher Vickers hardness values than Hunter-Schreger band enamel does. Radial enamel is located in the outer zone of enamel thickness, while the inner zone is occupied by HSB enamel, except in the cervical zone where only radial enamel can be seen. Differences in hardness between both types of enamel would be influenced by the arrangement of prisms in each zone.

Enamel with bands exposed on the masticatory surface results to be less resistant to occlusal wear.
Combination of the different enamel types is needed in order to meet the biomechanical requirements and to achieve resistance to fracture and abrasion.

REFERENCES

(1) Boyde A, Fortelius M. Development, structure and function of rhinoceros enamel. Zool J Linn Soc. 1986; 87:181–214.
(2) Braly A; Darnell LA; Mann AB; Teaford MF; Weihs TP: The effect of prism orientation on the indentation testing of human molar enamel; Arch Oral Biol. 2007 Sep;52(9):856-60
(3) Durso,G; Abal,A; Anselmino,C ;Batista,S; Tanevitch,A; Iacoi M.: Types of enamel in the incisive tooth groups. BIOCELL 32(1), Inca Editorial, ISSN 0327-9545, 2008, pp. 108
(4) Goin, F; Durso, G; Anselmino, C; Batista, S; Tanevitch, A; Abal, A: Microestructura del esmalte dentario: definiciones y conceptos. R.A.O.A. Buenos Aires, , 2007 oct.- dic., 95 (5): 393-398
(5) Jiang Y; Spears, IR; Macho, GA : An investigation into fractured surfaces of enamel of modern human teeth: a combined SEM and computer visualization study. Archs. Oral Biol. 2003, 48: 449-457
(6) Koenigswald, W; Clemens, W: Levels of complexity in the microstructure of mammalian enamel and their application in studies of systematic. Scanning Microscopy, 1992, 6: 195-218
(7) Koenigswald, W; Goin, F: Enamel differentiation in South American marsupials and comparision of placental and marsupial enamel. Paleontographica. Abt.A.B. 2000, 225: 137-141
(8) Koenigswald, W; Sander, P: Glossary of terms used for enamel microstructures en: *Tooth enamel microstructure.* Koenigswald, W; Sander, P (eds.) Balkema, Rotterdam, 1997, pp 267-297
(9) Lynch, CD; O´Sullivan, VR; Dockery, P; McGillycuddy, CT; Rees, JS; Sloan, AJ: Hunter-Schreger Bands patterns and their implications for clinical dentistry J. Oral Rehabil. 2011, 38 (5): 359-65
(10) Maas, MC: Enamel structure and microwear: an experimental study of the response of enamel to shearing force. Am. J. Phys. Anthropol. 1991 May; 85(1): 31-49
(11) Meredith N, Sherriff M, Setchell DJ, Swanson SA.: Measurement of the microhardness and Young's modulus of human enamel and dentine using an indentation technique. Arch Oral Biol. 1996 Jun; 41(6):539-45.
(12) Rensberger, J: Mechanicals adaptation in enamel; en: Tooth enamel microstructure, Koenigswald, W; Sander, P (eds.) Balkema, Rotterdam, 1997, pp 237-257
(13) Xu HH, Smith DT, Jahanmir S, Romberg E, Kelly JR, Thomson VP, Rekow ED: Indentation damage and mechanical properties of human enamel and dentin.J Dent Res.1998 Mar;77(3):472-80