ARTICLE IN PRESS

Journal of Dentistry xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Trend-analysis of dental hard-tissue conditions as function of tooth age

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ARTICLE INFO

Keywords:
Aging
Enamel
Dentin
Caries
Tooth wear
Fluorosis
Tooth color

ABSTRACT

Objective: This retrospective in-vitro study investigated tooth age effect on dental hard-tissue conditions.
Methods: Unidentified extracted premolars (n = 1500) were collected and their individual age was estimated (10–100 (± 10) years old (yo)) using established dental forensic methods Dental caries, fluorosis and tooth wear (TW) were assessed using the International Caries Detection and Assessment System (ICDAS; 0–5 for crown and 0–2 for root), Thylstrup-Fejerskov (TFI; 0–9) and Basic Erosive Wear Examination (BEWE; 0–3) indices, respectively. Staining and color were assessed using the modified-Lobene (MLI) (0–3) and VITA shade (B1-C4) indices, respectively. Relationships between indices and age were tested using regression models.
Results: Starting at age ∼10yo, presence of caries increased from 35% to 90% at ∼50yo (coronal), and from 0% to 35% at ∼80yo (root). Caries severity increased from ICDAS 0.5 to 2 at ∼40yo and from ICDAS 0 to 0.5 at ∼60yo for coronal and root caries, respectively. Presence of TW increased from 25% (occlusal) and 15% (smooth-surfaces) to 100% at ∼80yo. TW severity increased from BEWE 0.5 to 2 at ∼50yo (occlusal) and ∼0.3 to 1.5 at ∼50yo (smooth-surfaces). Percentage and severity of fluorosis decreased from 70% to 10% at ∼80yo, and from TFI 1 to 0 at ∼90yo, respectively. Percentage of extrinsic staining increased from 0% to 85% at ∼80yo and its severity increased from MLI 0 to 2 at ∼70yo. Color changed from A3 to B3 at ∼50yo (crown), and from C2 to A4 at ∼85yo (root).
Conclusions: Aging is proportionally related to the severity of caries, TW, staining, and inversely to dental fluorosis. Teeth become darker with age.

1. Introduction

Population aging is a global trend, and the percentage of older individuals (65+) is expected to more than double over the next half century [1]. Aging is defined as the cumulative and progressive change that occurs with time, causing deterioration in structural integrity, as well as increase in disease susceptibility and debilitated function [2].

Besides improvement in dental health awareness and preventive measures, age may also impact propensity for dental diseases. Tooth aging is related to several behavioral (environmental) and biological (tooth) factors. Teeth suffer different mechanical and chemical insults throughout a person's life. The accumulation of these experiences may affect the properties and behavior of dental hard tissues. Several microstructural changes have been correlated with age, including increase in mineral content, decrease in organic bridging ligaments at enamel rods and dentin tubular occlusion [3,4]. These changes are likely to impact enamel and dentin mechanical, physical and chemical properties. Increase in brittleness and decrease in fracture toughness with age cause an overall reduction on the mechanical strength of enamel and dentin [4]. Other properties, including solubility, ion exchange and tooth color may also alter with age. Consequently, the susceptibility to demineralization (as in dental caries and erosion), rate of remineralization, and tooth shade may change as well. Moreover, behavioral aspects such as diet and oral hygiene may significantly impact the presence of those diseases and conditions as well as tooth appearance, including abraded fluorotic enamel and tendency to retain more extrinsic staining.

Despite the importance of this topic, scarce data are available in

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https://doi.org/10.1016/j.jdent.2018.05.011
Received 11 April 2018; Received in revised form 15 May 2018; Accepted 17 May 2018
0300-5712/

literature to allow deeper understandings of the age impact on dental hard-tissue conditions. Major limitations of longitudinal clinical studies, such as time and costs, prohibit conducting a comprehensive evaluation of their prevalence and severity. Meta-analyses from previous clinical studies are limited, due to lack of robust retrospective data of different ages. Considering these circumstances, we propose that a systematic laboratory approach using extracted teeth with estimated ages can be valuable. Tooth aging manifests a highly predictable developmental sequence of morphological and biochemical changes, which allows the forensic identification of an individual's age using mathematical models [5,6].

We hypothesized that individual's susceptibility to dental hard-tissue diseases and conditions change throughout life, suggesting a need for age-specific clinical preventive and therapeutic protocols. In the current study, we started exploring this hypothesis by evaluating the occurrence of clinically common dental problems in a large set of extracted human premolars, with a broad age range. Our unique experimental approach consisted of using established forensic methods to estimate tooth age, and established clinical indexes to assess dental pathologies and conditions, as well as staining and color.

2. Materials and methods

2.1. Teeth collection

A sample of 1500 extracted human premolars were randomly selected from an existing pool (approximately 18,000 premolars) at the Oral Health Research Institute (OHRI), Indiana University School of Dentistry (Indiana University IRB # NSO 911-07). This tooth-bank was compiled through teeth collection from dental practice clinics across the USA over several years. Upon receipt at OHRI, teeth were sorted, gently cleaned from tissue remnants and kept in 0.1% thymol, at 4 °C. Patient metadata (e.g., age, sex, reason for extraction) were not available, rendering all samples unidentifiable. Our exclusion criteria included advanced caries lesion (i.e. International Caries Detection and Assessment System [ICDAS] index 6) [7], restored and fractured teeth. Sampling was performed randomly assuming similar distribution among five empiric age categories with 15 year-intervals (< 25; 25–40; 41–54; 55–70; > 70) to ensure proper coverage of a wide age range. Using approximately 300 teeth per age category, pathologies' presence could be estimated within the range 50% (± 6%) to 3.5% (± 2.3%), and would have 80% power to detect odds ratios for age of 1.5 or less, assuming 5% significance level and 3.5% disease presence.

2.2. Age estimation

Tooth age was estimated using one of two established forensic methods. The Liversidge and Molleson [1999] [8] method was used to estimate the age of not yet fully developed teeth, which comprised 10.7% of our sample. After measuring the distance between the buccal cusp tip and the edge of the developing root at the midline, age was estimated by applying the formula $A = b0 + b1\times$; where (A) is the estimated age, ($\times$) is the developing tooth length, and (b0, b1) are coefficients for each tooth type (1st or 2nd premolars, in our study).

The Bang and Ramm [1970] [9] method was used to estimate the age of fully developed teeth based on root dentin translucency. The minimal and maximal translucency length values (TL 1 and 2, respectively) from the apex to the borderline of opaque root dentin coronally were recorded. The average of TL1 and TL2 (TM) was used to estimate the age (A) applying the formulae $A = B0 + B1\times + B2\times^2$ (for TM ≥ 9.0 mm) or $A = B0 + B1\times$ (for TM < 9.0 mm); where B0, B1, B2 are coefficients for each tooth type. A single trained examiner performed the measurements using a digital sliding caliper (Fisher Scientific, Waltham, MA, USA).

2.3. Outcome measures

Coronal and root caries lesions were recorded on all surfaces according to ICDAS-II criteria [7]. Enamel fluorosis was recorded on buccal, lingual and occlusal surfaces using the Thylstrup-Fejerskov Index (TFI) [10] (TFI). Tooth wear was scored on occlusal, buccal and lingual surfaces, using the Basic Erosive Wear Examination (BEWE) index [11]. For buccal and lingual surfaces, two digits were given; the first digit represented the severity, while the second digit represented the location of tooth wear (TW) [12] to study the percentage of non-carious cervical lesions (NCCL) in different ages. Presence and severity of extrinsic staining was assessed on buccal and lingual surfaces, using the two-digits modified-Lobene index (MLI), in which the first and second digits represent staining intensity and extent, respectively [13]. The shade at the middle third of facial surfaces of crowns and roots was evaluated using a digital spectrophotometer (VITA Easyshade, Vident, USA) and recorded based on VITA classical A1-D4 shade guide.

2.4. Statistical analysis

Intra-examiner repeatability for the translucency measurement and inter-examiner agreement for ICDAS, BEWE, TFI, and MLI compared to gold standard and senior dentist, were evaluated using the intra-class correlation coefficient (ICC).

Presence of caries lesions, enamel fluorosis, tooth wear, staining and color were estimated and plotted against tooth age. A simulation-based analysis was performed to account for measurement error of the age assessments (± 10 years) when evaluating the relationship between age and the outcomes. The simulated analysis used 1000 replications, wherein a normally distributed random error with mean 0 and standard deviation 10 was added to each age measurement. The nonlinear regression analysis was fitted for each simulated dataset. The point-wise median and 5th and 95th percentiles of the nonlinear regression lines were estimated and plotted in the graph.

3. Results

Our sample showed similar distributions for maxillary (50.6%) and mandibular (49.4%) premolars. Although the sample represented a wide age range (9–101yo), the distribution was unbalanced at the highest end, with fewer teeth ≥ 80yo. This should be considered when interpreting and comparing data obtained from those ages. ICC revealed excellent intra-examiner agreement for average translucency (0.92), and inter-examiner agreement for TFI (0.97) and staining intensity (0.90). Acceptable inter-examiner agreement was observed for BEWE location (0.67) and severity (0.72), staining extent (0.77), and ICDAS (0.77).

Overall, percentage and severity of coronal and root caries increased with age, with higher numbers observed for coronal caries (Fig. 1). TW percentage and severity for both occlusal and smooth surface, as well as occurrence of NCCL increased with age (Fig. 2). Percentage and severity of enamel fluorosis decreased with age (Fig. 3). Extrinsic staining presence, severity and extent increased with age, with higher extent observed in the lingual surface (Fig. 4). Mean VITA classical shade increased for both crown and root, with more evident results for root (Fig. 5).

4. Discussion

Time, costs and ethical concerns limit the study of age's effect on dental hard-tissue pathologies and conditions in a clinical setting. Our in-vitro approach, based on the age-estimation of unidentified extracted teeth using forensic methods, allowed us to investigate a relatively large number of teeth under very controlled conditions. We selected premolars for practical reasons since they are extracted at a wide age-range due to orthodontics, prosthodontics, and periodontal disease progress.