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Age-related changes in hardness and modulus of elasticity of dentine

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Modulus of elasticity;
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Morphological change

Summary

Objectives: Little knowledge has been clarified about the relationship between the morphological and physical changes of dentine during aging. The purpose of this study was to clarify the modulus of elasticity and hardness related to the morphological changes of dentine by aging using a transmitted light microscope (TLM) and a nano-hardness tester (NHT).
Methods: Aged human molars and young third molars were used. The dentine morphology was observed under a TLM. The hardness and Young's modulus of elasticity related to the morphologic study were evaluated with an NHT.
Results: The thickness of mantle dentine and globular dentine of aged teeth were less than that of young teeth. Transparent dentine was observed only underneath the attrition of young teeth. Reactionary tertiary dentine formed and a "dark zone" was found at the junction between physiologic secondary and reactionary dentine only in aged teeth. At the mantle dentine, hardness and modulus of elasticity of aged dentine were higher than those of young dentine. The reactionary dentine in aged teeth and newly developed secondary dentine in young teeth demonstrated lower modulus of elasticity and hardness than those of other circumpulpal dentine. Relatively low modulus of elasticity and hardness were observed at the zone between secondary and reactionary dentine.

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Conclusions: Changes in dentine due to aging resulted in transformation of morphological features causing changes to their hardness and modulus of elasticity at the explicit areas such as the increase of hardness and modulus of elasticity at mantle dentin and the reduction of these properties at the ''dark zone'' that found in aged teeth.

Introduction

Geriatric dentistry has received increasing attention due to the extension of the human life span.[1,2] Attrition is one of the general factors which cause tooth wear.[3,4] The tooth wear is a normal physiological process. Only when the adaptive capabilities of the individual are surpassed, pathological problems become evident.[5–7]

The attrition of teeth causes changes in morphological features such as enamel wear, transparent dentine formation and production of reactionary dentine.[8–10] Little information is available about the relationship between the morphological and physical change of dentine on the progression of wear. This knowledge is important for understanding their mechanical behavior under clinical loading conditions.

The hardness of teeth has often been reported using micro-hardness tests.[11–13] The knoop hardness of human young normal dentine was about 60 kg/mm^2, that of aged transparent dentine was about 80 kg/mm^2 and that of aged reparative dentin was about 40 kg/mm^2 were reported individually. There were a few studies that have evaluated the differences of mechanical properties between transparent aged dentine and normal young dentine.[14,15] They showed no significant differences in mechanical properties between transparent aged dentine and normal young dentine. However, no studies was performed to investigate the mechanical properties of aged and young dentine at small specific areas such as dentino-enamel junction (DEJ), mantle dentine, globular dentin, transparent dentine or tertiary dentine. Due to the appropriate size of nano-hardness indentors when compared with micro-hardness indentors, it is possible to assess the precise hardness and Young's modulus of small specific areas.[16,17]

The purpose of this study was to clarify hardness and modulus of elasticity related to the morphological changes of dentine associated with wear. Morphological features of dentine were observed using transmitted light microscopes (TLM), and hardness and modulus of elasticity were measured by a nano-hardness tester.

Materials and methods

This project was approved by the ethics committee of the Tokyo Medical and Dental University. Ten extracted aged molars from elderly individuals with enamel attrition without any dentine exposure and 10 extracted unoccluded intact young third molars from adolescents were used in this study. All teeth were extracted for pathological reason and the patients were informed and agreed the use of their teeth for this investigation. The average age of the elderly patients was 61 $\pm$ 6.0 years and the adolescent was 22 $\pm$ 2.7 years. The teeth were kept in physiological saline solution at 5 °C until use within 2 months. The changes of hardness and modulus of elasticity related to the morphological changes were established at $p < 0.05$.

Preparation of specimens

Each tooth was embedded in a plastic ring with epoxy resin (EPON 815, Nisshin EMG, Tokyo, Japan) and was sectioned bucco-lingually with a diamond saw microtome (Leitz 1600, Leica Instruments, Heidelberg, Germany) to create a 150 μm thick section from center of teeth leaving two pieces about 5 mm thick specimens on each side of the section.

Observation using a TLM

The 150 μm thick slabs were reduced to approximately 100 μm with silicon carbide papers by hand lapping. The specimens were observed for micromorphological structures under a TLM (Vanox AHBS3, Olympus, Tokyo, Japan). The morphological structures identified were dentino-enamel junction, mantle dentine, globular dentine, primary and physiologic secondary dentine, transparent dentine and tertiary reactionary dentine.[18] The thickness of each area was measured.

Hardness test

The remaining two 5 mm thick specimens from each tooth were polished with wet silicon carbide papers (600 to 1200 grit) and diamond pastes (6, 3, 1 and 0.25 μm) and used for nano-hardness testing