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Evolution of the Pulp Chamber Throughout Life: Microscopic Analysis of Dentin Remodeling in Human Molars

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LITERATURE REVIEW

ABSTRACT

Objective: This study aims to analyze the morphological changes in the pulp chamber throughout life, focusing on the microscopic remodeling of dentin in human molars. Understanding these structural modifications is essential for improving clinical approaches in Endodontics and Restorative Dentistry. **Materials and Methods:** A systematic literature review was conducted using multiple databases, including PubMed, SciELO, BVS BIREME, and ScienceDirect. Studies were selected based on their relevance to dentin remodeling, secondary and tertiary dentin deposition, and age-related changes in the pulp chamber. Key descriptors such as "Dental Pulp Cavity," "Dentin," and "Endodontics" guided the research. Microscopic and radiographic analyses of molars at different age stages were also considered. **Results:** The progressive deposition of secondary dentin leads to a volumetric reduction of the pulp chamber, with more significant changes in the ceiling and floor regions. Radiographic evidence suggests that this process becomes more pronounced after the third decade of life. Additionally, external stimuli, such as caries, trauma, and restorative procedures, accelerate tertiary dentin formation, influencing pulp vitality and endodontic treatment complexity. These modifications impact pulp sensitivity, root canal accessibility, and the overall response to dental treatments. **Conclusion:** The continuous remodeling of the pulp chamber due to secondary and tertiary dentin deposition significantly affects endodontic and restorative procedures. Clinicians must consider these age-related changes when planning treatments to optimize therapeutic outcomes. A deeper understanding of dentin remodeling mechanisms will contribute to better dental care strategies, ensuring long-term tooth health and function.

Keywords: Dental Pulp Cavity; Dentin; Endodontics.

Evolução da Câmara Pulpar ao Longo da Vida: Análise Microscópica da Remodelação Dentinária em Molares Humanos

RESUMO

Objetivo: Este estudo tem como objetivo analisar as alterações morfológicas na câmara pulpar ao longo da vida, com foco na remodelação microscópica da dentina em molares humanos. Entender essas modificações estruturais é essencial para melhorar as abordagens clínicas em Endodontia e Odontologia Restauradora. **Materiais e métodos:** Uma revisão narrativa foi conduzida usando vários bancos de dados, incluindo PubMed, SciELO, BVS BIREME e ScienceDirect. Os estudos foram selecionados com base em sua relevância para a remodelação da dentina, deposição de dentina secundária e terciária e alterações relacionadas à idade na câmara pulpar. Descritores-chave como "Cavidade da polpa dentária", "Dentina" e "Endodontia" orientaram a pesquisa. Análises microscópicas e radiográficas de molares em diferentes estágios de idade também foram consideradas. **Resultados:** A deposição progressiva de dentina secundária leva a uma redução volumétrica da câmara pulpar, com mudanças mais significativas nas regiões do teto e do assoalho. Evidências radiográficas sugerem que esse processo se torna mais pronunciado após a terceira década de vida. Além disso, estímulos externos, como cáries, traumas e procedimentos restauradores, aceleram a formação da dentina terciária, influenciando a vitalidade da polpa e a complexidade do tratamento endodôntico. Essas modificações impactam a sensibilidade da polpa, a acessibilidade do canal radicular e a resposta geral aos tratamentos odontológicos. **Conclusão:** A remodelação contínua da câmara pulpar devido à deposição de dentina secundária e terciária afeta significativamente os procedimentos endodônticos e restauradores. Os clínicos devem considerar essas mudanças relacionadas à idade ao planejar tratamentos para otimizar os resultados terapêuticos. Uma compreensão mais profunda dos mecanismos de remodelação da dentina contribuirá para melhores estratégias de cuidados dentários, garantindo a saúde e a função dos dentes a longo prazo.

Palavras-chave: Câmara Pulpar; Dentina; Endodontia.

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INTRODUCTION

The pulp chamber is a dynamic and highly specialized structure, whose morphology undergoes continuous modifications throughout life due to the progressive deposition of secondary and tertiary dentin. The interrelationship between the dental pulp, dentin and enamel configures the so-called pulp-dentin complex, an integrated functional unit that responds to physiological and pathological stimuli in a coordinated manner (Pashley DH et al., 2002).

The dental aging process causes significant changes in this complex, reflected in the three-dimensional volumetric reduction of the pulp chamber, as well as in the decrease in vascularization and progressive tissue fibrosis (Bernick S, Nedelman C, 1975). Initially, the pulp is wide, well vascularized and with high cell density, characteristics that favor its capacity for immunological and regenerative response (Kim S, 1990). Over time, however, there is an increase in the deposition of reactive and sclerotic dentin, making the pulp tissue progressively less flexible, with a reduction in the space available for vascular and nervous components (Heyeraas KJ, Berggreen E, 1999). These changes can compromise pulp vitality, directly influencing the response to restorative and endodontic procedures, in addition to impacting sensory perception and the mechanical resistance of the dental structure (Schroeder HE, 1986). In addition to the inevitable process of senility, the dental pulp invariably responds with the production of mineralized tissue in the face of low-intensity trauma (Stanley HR, 1989). Several factors, both intrinsic and extrinsic, modulate these structural changes. Among the physiological factors, the activity of odontoblasts and fibroblasts stands out, which continue to synthesize the dentin matrix throughout life (Goldberg M, Smith AJ, 2004). Among the pathological factors, caries, occlusal trauma and invasive procedures can accelerate the deposition of tertiary dentin and alter pulp homeostasis (Seltzer S, Bender IB, 1984). Thus, understanding the mechanisms underlying dentin remodeling throughout life is essential to improve clinical approaches in Endodontics and Restorative Dentistry, through knowledge of the structural changes that inevitably occur in all dentate mammals.

In this context, the present study proposes a detailed microscopic analysis of the structural changes of the pulp chamber in human molars, correlating them with age and

the biological processes that govern dentin remodeling. This approach will allow a better understanding of the influence of aging on pulp morphology and its implications for dental practice.

MATERIALS AND METHODS

During the development of this narrative review article, it was essential to establish a methodological strategy to ensure the inclusion of the most current, relevant, and scientifically validated information on the topic, providing robust and well-supported content. Searches were conducted across multiple databases, including DeCs, BVS/BIREME, PROSPERO, SciELO, PubMed Central, ScienceDirect, Web of Science, and The Cochrane Library, in conjunction with Google Scholar. Additionally, gray literature was utilized to provide supplementary and relevant insights, which proved crucial for a comprehensive exploration of the subject matter. To refine the scope and relevance of the searches, the following descriptors were employed: Maxillofacial Injuries; Child Abuse and Clinical Epidemiology. Given the narrative review format, it was necessary to adopt a framework that defines the structure, essential elements, and exclusions pertinent to this type of study. Consequently, Rother's (2007) work served as a methodological guide throughout the preparation of this article, ensuring consistency and adherence to the standards of narrative literature reviews.

LITERATURE REVIEW

Secondary dentin is continuously deposited by odontoblasts after complete formation of the tooth root, promoting a progressive reduction in the pulp chamber space, a phenomenon known as pulp self-enclosure. This process is most evident in the regions of the ceiling and floor of the chamber, but also occurs in the proximal walls, resulting in an overall decrease in pulp volume (Holland et al., 2019). It is interesting to observe the pulp chamber of individuals under 20 years of age, between 20 and 40 years of age, and over 50 years of age, as can be seen in Figure 1 (left side), figure 1 (center) and figure 1 (right side).

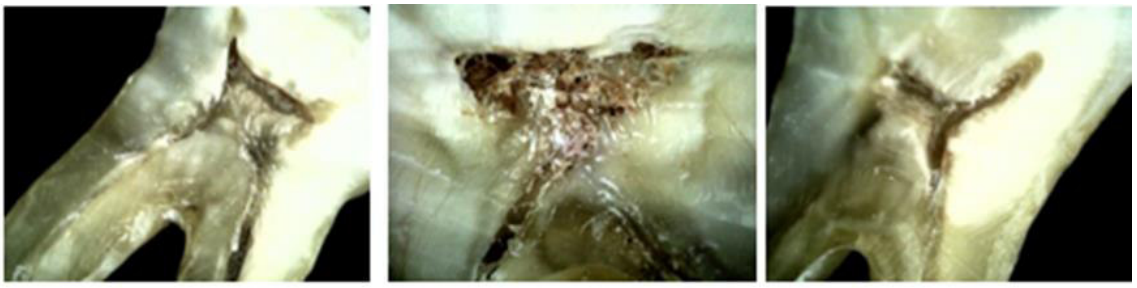

Figure 1 (left side): Observe the volumetric amplitude of the pulp chamber in an individual under 20 years of age. **Figure 1 (center):** Note the reduction of the proximal walls of the pulp chamber in a 35-year-old individual. Note that there is still amplitude, but in the mesiodistal direction the chamber appears reduced. **Figure 1 (right side):** Finally, the three-dimensional reduction can be seen in a 60-year-old individual. Observe the floor and ceiling relationship in the three cases.

Radiographically, this reduction becomes noticeable from the third decade of life (Ten Cate, 2013). However, due to the increasing adoption of restorative and prosthetic procedures, a recent phenomenon called premature pulp aging has been observed, characterized by an acceleration of this process even in young individuals (Bjørndal & Darvann, 1999). In this sense, in teaching three decades ago, it was possible to estimate the age of patients through radiographic analysis, which is no longer the case today. Changes in the pulp chamber also extend to the root canals (Figure 2).

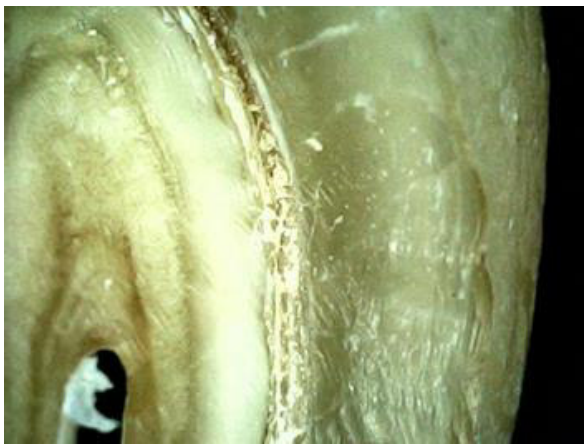

Figure 2: Observe the atresia of the cervical third of the mesial canals of tooth 36 in a 50-year-old individual. The production of secondary dentin is capable of promoting self-

enclosure of the pulp in all dimensions, extending to the root canals, resulting in the degree of difficulty in orthodontic treatment.

At the same time, mineral deposition in the dentinal tubules leads to dentin sclerosis, reducing permeability and promoting partial or complete obliteration of the tubules, which protects the pulp against external aggressions, but also compromises its ability to respond to physiological and pathological stimuli (Mjor & Nordahl, 1996).

When subjected to external stimuli, such as caries, trauma or restorative interventions, the dentin-pulp complex responds with the formation of tertiary dentin, which acts as a protective barrier against the progression of lesions. This dentin can be reactive, when formed by surviving odontoblasts that increase their secretory activity, or reparative, when new odontoblasts differentiate from pulp stem cells due to cell necrosis of the original odontoblasts (Smith et al., 1995). This tissue has a variable structural organization and greater mineralization compared to physiological dentin, and is generally less tubular and more irregular. The main purpose of deposition is to obliterate the lumen of the dentinal tubules and prevent microbial invasion, usually caused by bacteria and, in some cases, fungi and viruses (Love, 2001).

Structural changes in the pulp and dentin affect the response to pulp sensitivity tests. In teeth with a smaller pulp chamber, the transmission of stimuli may be altered, requiring a longer contact time between the thermal agent and the tooth surface to evoke a response (Brännström, 1986). This occurs due to reduced blood circulation and changes in the hydrodynamic effects of the pulp, especially impacting elderly individuals or those with parafunctional habits, such as bruxism.

These structural changes also have significant clinical implications in endodontic treatment. The reduction in pulp space makes it difficult to locate and access the root canals, increasing the risk of iatrogenic perforations (Peters, 2004). Furthermore, the presence of tertiary dentin, due to its irregular mineralization and lower tubular organization, can hinder permeability, instrumentation and effective irrigation of the canals, requiring more refined clinical approaches to ensure adequate decontamination of the root canal system (Schroeder et al., 2021). Thus, the assessment of dental age and the degree of dentin remodeling is essential for more accurate and effective endodontic

planning.

RESULTS AND DISCUSSION

Understanding the processes of secondary and tertiary dentin formation is essential for planning and implementing effective endodontic treatments. Practitioners should be aware of the morphological changes in the pulp chamber associated with aging and adaptive responses to external stimuli, adjusting their techniques and therapeutic approaches as necessary. Future studies should deepen the understanding of the mechanisms of dentin remodeling and its implications for tooth longevity and health.

CONCLUSION

The continuous deposition of secondary dentin throughout life results in a volumetric reduction of the pulp chamber, while the formation of tertiary dentin reflects adaptive responses to external stimuli. These changes directly impact clinical endodontic practice, requiring professionals to consider dental age and the state of dentin remodeling when planning and executing treatments. A thorough understanding of these processes is essential for therapeutic success and the longevity of treated teeth.

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