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Comparison of Dentin Tensile Strength of Impacted Teeth Versus Erupted Teeth: A Comparative Analytical Study

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Abstract

Objectives: Dentin provides the primary structural foundation of the human tooth, playing a critical role in distributing masticatory forces and supporting the overlying enamel. This in vitro study aimed to evaluate and compare the ultimate dentin tensile strength of completely impacted human teeth versus fully erupted functional teeth.

Materials and Methods: Sound human erupted teeth and completely impacted teeth were collected following extraction for clinical indications. The specimens were sectioned to isolate standardized dentin blocks, ensuring the exclusion of enamel and pulpal soft tissues. Tensile strength evaluation was carried out using a specialized multi-test universal testing device. Uniaxial tensile load was applied at a constant crosshead speed until specimen failure occurred. Continuous data recording captured the maximum force (N), tensile stress at tensile strength (MPa), tensile strain at break (%), and ultimate tensile stress at break (MPa) for both cohorts.

Results: The ultimate tensile stress at break for the dentin of impacted teeth was found to be 6.21 MPa, which was substantially higher than that of erupted teeth, which demonstrated a tensile stress at break of 2.79 MPa. Impacted teeth also exhibited a higher maximum force tolerance (71.68 N) compared to erupted teeth (31.50 N). Furthermore, the tensile stress at tensile strength reached 9.62 MPa for impacted dentin compared to 4.50 MPa for erupted dentin, while the tensile strain at break was 4.55% and 0.84%, respectively.

Conclusion: The dentin of completely impacted teeth possesses significantly superior tensile strength and strain capacity compared to the dentin of erupted teeth. These findings indicate that exposure to the oral environment, physiological aging, and functional masticatory loading significantly alter the mechanical properties and resilience of dentin substrates.

Keywords: Dentin, Tensile Strength, Impacted Teeth, Erupted Teeth, Mechanical Properties, Restorative Dentistry

Introduction

Dentin forms the bulk of the hard tissue complex of the human tooth and acts as the primary buffering substrate against mechanical trauma, masticatory loads, and functional stresses [1]. It is situated between the highly mineralised enamel layer externally and the pulp chamber internally, serving as a critical intermediary that absorbs and distributes occlusal forces. Structurally, dentin is recognised as the second hardest tissue in the human body, surpassed only by the enamel layer which covers the anatomical crown [2]. It is a complex, naturally occurring composite substrate comprising approximately 70% inorganic mineral components by weight, structurally arranged as hydroxyapatite crystals embedded within a collagenous framework, and 30% organic matrix composed primarily of type I collagen fibres, water, and specialised mucopolysaccharides [3, 4]. This specific structural organisation imparts both high compressive rigidity and essential tensile resilience to the tooth structure. The combination of these mechanical properties is crucial for preventing catastrophic brittle fractures of the friable enamel shell under occlusal loading, as the dentin layer acts as a shock absorber that dissipates and distributes the forces generated during mastication [5].

Tensile strength is a fundamental mechanical property that governs the capacity of a dental hard tissue substrate to resist tearing, deformation, and structural failure when subjected to tensile forces [6]. In contrast to compressive strength, which measures resistance to crushing forces, tensile strength reflects the material's ability to withstand pulling or stretching forces without fracturing. In clinical practice, evaluating the mechanical behaviour and tensile limits of various dentinal substrates is of paramount importance for the progression and optimisation of modern restorative therapies [7]. The success of adhesive restorations, for instance, depends on the ability of the restorative material to bond effectively to the dentin substrate, and this bonding is influenced by the tensile characteristics of the underlying tissue. A comprehensive understanding of these underlying mechanical mechanisms provides crucial insights into how adhesive systems interface with both enamel and dentin architectures, informing the development of more durable and predictable restorative techniques [8].

Throughout the lifespan of a functional, erupted tooth, the dentinal substrate undergoes continuous modifications in response to both physiological and pathological stimuli [9]. The tooth is continuously exposed to a dynamic oral environment characterised by cyclical masticatory loading, structural fatigue from repetitive functional demands, thermal fluctuations from food and fluid intake, and chemical challenges from dietary acids and microbial byproducts [10]. These constant external stimuli provoke a series of physiological defence mechanisms within the dentin-pulp complex. The progressive deposition of secondary dentin occurs as a natural aging phenomenon, reducing the pulp chamber volume and altering the overall structural composition of the dentin. Simultaneously, the development of intratubular dentin sclerosis represents a protective response in which the dentinal tubules become progressively occluded by mineral deposits, thereby reducing permeability and enhancing structural integrity [11]. These age-related and functional adaptations systematically alter the original tubular architecture, modify the mineral-to-organic ratio, and ultimately influence the overall mechanical properties of the dentin substrate.

In stark contrast, completely impacted teeth remain sequestered within the alveolar bone socket, completely insulated from the physical, chemical, and thermal variations of the open oral cavity [12]. These teeth are not subjected to the functional loading patterns that characterise masticatory activity. They are also not directly exposed to dietary acids, temperature fluctuations, or the microbial challenges that continuously affect erupted teeth. As a result, impacted teeth do not develop the same physiological defence mechanisms, such as secondary dentin deposition or dentin sclerosis. The mineral-to-organic ratio, tubular architecture, and overall mechanical properties of impacted dentin may therefore differ significantly from those of functionally matured erupted dentin.

Although multiple investigations have analysed the compressive and shear strength of human dentin under various conditions, limited comparative focus has been directed toward analysing the ultimate tensile characteristics of unexposed impacted dentin versus functionally matured erupted dentin. Understanding these differences is clinically significant, as it may influence the selection of restorative materials, the design of adhesive protocols, and the prediction of treatment outcomes for teeth that have been functionally compromised. Therefore, the aim of this comparative analytical study was to quantitatively evaluate and compare the dentin tensile strength of completely impacted human teeth against that of fully erupted human teeth using a precise computerised multi-test testing framework.

Materials and Methods

Sample Selection and Preparation

This comparative in vitro analytical investigation was conducted within the experimental testing facilities of Saveetha Dental College and Hospitals, Chennai, India. Prior to initiation, the study protocol was reviewed and granted formal approval by the Institutional Review Board and Ethical Committee of Saveetha Dental College. Human teeth extracted for therapeutic reasons—such as orthodontic treatment, periodontal disease, or therapeutic surgical removal of impacted third molars—were collected after obtaining written, informed consent from the donors.

The sample criteria comprised two main experimental groups. Group 1 consisted of sound, caries-free human permanent teeth that had reached full occlusion and were functional within the oral cavity. These teeth were classified as erupted teeth. Group 2 consisted of completely impacted sound human permanent teeth exhibiting full root formation but retained entirely within bone, with no direct exposure to the oral cavity environment. Teeth presenting with structural microcracks, deep dental caries, previous restorative interventions, developmental defects, or signs of internal or external resorptive processes were strictly excluded from sample selection. Following extraction, any attached soft tissue debris and periodontal ligament remnants were meticulously removed using manual periodontal scalers. The cleaned teeth were then disinfected in a 0.1% thymol solution and stored in distilled water at room temperature to preserve natural hydration status prior to mechanical processing.

Specimen Sectioning and Standardized Dimensioning

To prepare standardized dentin test blocks, the teeth were oriented and stabilized within a high-precision low-speed diamond-blade sectioning saw under continuous, copious water cooling. This cooling was essential to mitigate frictional heat generation and prevent thermal denaturation of the organic collagen framework. The enamel crowns and radicular cementum layers were systematically removed to expose the middle coronal dentin zone. The isolated dentin structures were further sectioned down into uniform slab geometries. The longitudinal configuration of the dentinal tubules was kept as uniform as possible across the samples. Microscopic evaluation was carried out during preparation to guarantee the complete elimination of peripheral enamel remnants and pulpal roof structures. The specimens were finished down with ultra-fine silicon carbide abrasive papers to eliminate surface flaws and parallelize the primary loading surfaces.

Mechanical Tensile Strength Testing

Mechanical testing was performed utilizing a calibrated multi-test universal testing machine configured specifically for micro-tensile evaluation. The ends of each standardized dentin specimen were carefully secured into the custom-engineered gripping jaws of the tensile testing device. Alignment parameters were rigorously checked to ensure that the tensile vectors were applied perpendicular to the long axis of the specimen interface, ensuring purely uniaxial tensile stress delivery without introducing confounding bending or torsional moments.

The testing sequence was initiated at a stabilized, constant crosshead displacement speed. The real-time mechanical behavior of each specimen was continually tracked via a high-sensitivity electronic load cell linked directly to a computerized data-acquisition station. The system generated continuous force-displacement curves for each specific tooth specimen.

The analytical variables recorded during the testing sequence included maximum force in Newtons, which represented the peak load supported by the dentinal substrate prior to structural macroscopic failure. Tensile stress at tensile strength in

Megapascals was recorded as the maximum calculated tensile stress sustained by the specimen. Tensile strain at break percentage represented the total percentage elongation or displacement relative to the baseline specimen length recorded at the point of fracture. Tensile stress at break in Megapascals represented the ultimate stress value recorded precisely at the moment of physical material separation.

Following the failure of each individual specimen, the broken components were removed, and the cross-sectional dimensions at the actual fracture site were measured with a digital micrometer. The final calculations for stress were verified using the standard formula:

$\sigma = F / A$

where F represents the force in Newtons and A indicates the localized cross-sectional area in square millimeters.

Results

The quantitative data acquired from the force-displacement curves and mechanical evaluations revealed distinct differences in the structural properties between the two experimental groups. The precise mechanical profiles derived from the universal multi-test device are summarized in Table 1.

Specimen Group	**Specimen Label**	**Maximum Force (N)**	**Tensile Stress at Tensile Strength (MPa)**	**Tensile Strain at Break (%)**	**Tensile Stress at Break (MPa)**
Group 1	Normal (Erupted)	31.50	4.50	0.84	2.79
Group 2	Impacted	71.68	9.62	4.55	6.21

Analysis of Group 1 (Erupted Dentin)

The erupted dentin specimens exhibited a lower threshold for all mechanical parameters evaluated. The maximum force sustained by the erupted tooth dentin reached a peak value of 31.50 N. The maximum tensile stress achieved at its peak tensile strength was calculated at 4.50 MPa. When analyzing the deformation capabilities, the erupted dentin showed limited elasticity, yielding a tensile strain at break of only 0.84%. The ultimate tensile stress recorded at the precise point of structural break was 2.79 MPa. These lower values indicate that erupted dentin has reduced capacity to withstand tensile forces without fracturing, reflecting the cumulative effects of functional loading and environmental exposure on the structural integrity of the tissue.

Analysis of Group 2 (Impacted Dentin)

The completely impacted dentin specimens demonstrated a substantial increase across all measured mechanical attributes. The maximum force tolerance reached 71.68 N, representing more than double the load capacity observed in the erupted group. The peak tensile stress at tensile strength reached 9.62 MPa. The impacted dentin also showed a highly pronounced capacity for structural displacement before final failure, achieving a tensile strain at break of 4.55%. The final ultimate tensile stress sustained at the point of physical break was determined to be 6.21 MPa. These elevated values suggest that impacted dentin retains superior mechanical properties due to the absence of functional loading, thermal cycling, and chemical challenges that typically characterize the intraoral environment.

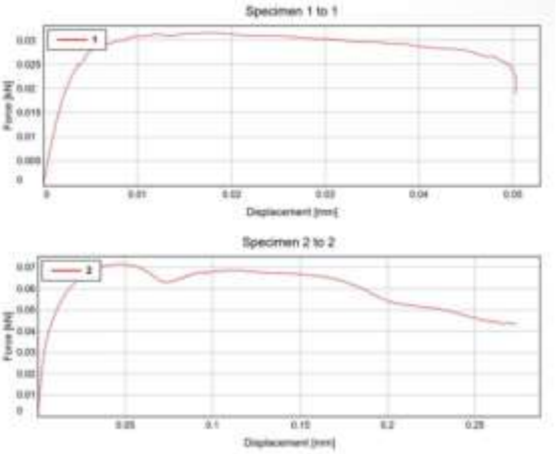

Figure 1. Uniaxial tensile force-displacement curves for erupted versus impacted human dentin specimens.

Top Panel (Specimen 1): Represents the characteristic tensile profile of erupted (normal) functional dentin. The curve demonstrates a lower peak load capacity (maximum force of 31.50 N / 0.0315 kN) and an immediate path to failure, yielding a low tensile strain profile (displacement terminating at approximately 0.05 mm).
Bottom Panel (Specimen 2): Represents the characteristic tensile profile of completely impacted dentin. The curve highlights a significantly higher mechanical threshold, demonstrating more than double the peak load capability (maximum force of 71.68 N / 0.0717 kN) alongside extended plastic deformation and structural displacement (terminating near 0.27 mm) prior to final material separation.

Discussion

The results of this comparative analytical investigation demonstrate a significant difference between the tensile mechanical properties of dentin derived from completely impacted teeth versus that of fully erupted functional teeth. The ultimate tensile strength at break of the impacted dentin, measured at 6.21 MPa, was found to be substantially higher than that of erupted dentin, which recorded 2.79 MPa. These findings underscore that the environmental exposure history, physiological modifications, and functional lifespan of a tooth significantly alter its underlying hard tissue characteristics [13]. To understand the marked superiority of impacted dentin's tensile strength, it is essential to examine the structural and micro-morphological differences between these two states. Dentin is a complex vital tissue that remains structurally dynamic throughout its existence [14]. In an erupted tooth, the tissue is subjected to continuous functional demands. The regular application of cyclic masticatory stresses induces micro-fatigue along the intertubular and peritubular dentin matrices [15]. Over years of function, these continuous micro-stresses can propagate ultra-structural micro-cracks throughout the collagen-hydroxyapatite network, lowering the total force required to cause cohesive material failure under tension. Furthermore, erupted teeth are exposed to continuous chemical, thermal, and biological challenges within the open oral environment [16]. Variations in oral fluid pH, exposure to bacterial metabolites, and thermal cycling from warm and cold intake induce consistent fluid movement within the dentinal tubules via hydrodynamic mechanisms. This environment promotes the formation of sclerotic dentin, a physiological mechanism characterized by the progressive hyper-mineralization and subsequent occlusion of the dentinal tubule lumens with apatite crystal deposits [17]. While this increased mineral deposition raises the overall surface microhardness and compressive rigidity of erupted dentin, it concurrently reduces the proportional volume of the highly resilient organic matrix. The organic component, predominantly composed of a well-organized type I collagen framework, provides the material with essential flexibility and the capacity to redistribute tensile stresses smoothly [18]. As the organic collagen network becomes restricted or undergoes age-related cross-linking changes, the dentin becomes more brittle. This brittleness is clearly reflected in the results of this study, where erupted dentin exhibited a low tensile strain at break of just 0.84%. In stark contrast, completely impacted teeth remain completely embedded inside the protective alveolar bone housing, shielded by both mucosal tissue and hard bone architectures. This complete encapsulation isolates the tooth from oral fluids, microbial acids, thermal shocks, and direct masticatory occlusal forces. Consequently, the pristine micro-structural arrangement of the dentinal tubules is preserved without the accelerated development of widespread sclerotic blockages or structural micro-fatigue. The organic collagen matrix retains its structural integrity, optimal hydration levels, and native viscoelastic parameters [19]. This preservation explains the highly pronounced structural elasticity observed in the impacted dentin group, which displayed an impressive tensile strain at break of 4.55% alongside a superior maximum force capacity of 71.68 N. The intact collagen network allows the impacted dentin substrate to absorb substantial tensile energy, distributing the localized stress concentrations efficiently across the material before macroscopic fracture occurs. The higher organic content and preserved tubular architecture of impacted dentin provide a more favorable substrate for energy dissipation, preventing the rapid propagation of cracks that characterizes the more brittle erupted dentin.

From a clinical and bio-material perspective, a detailed understanding of these varying tensile baselines provides essential parameters for advancing contemporary restorative dentistry [20]. Modern adhesive protocols rely thoroughly on micromechanical hybridization, where hydrophilic resin monomers must infiltrate an acid-etched dentinal collagen meshwork to construct a stable hybrid layer. Because the physical structure, mineral density, and organic elasticity of dentin vary dramatically based on whether a tooth has been functionally erupted or clinically impacted, the performance, bond longevity, and stress distribution of dental restorations will adapt accordingly. Recognizing that impacted dentin provides an inherently tougher, more elastic substrate could guide the optimization of restorative materials engineered to match the mechanical profiles of specific dentinal substrates, maximizing clinical durability and preventing adhesive-cohesive failures at the material interface.

The clinical implications of these findings are particularly relevant for restorative procedures involving teeth that have been functionally compromised or for cases where impacted teeth are surgically exposed and brought into occlusion. In such scenarios, the mechanical properties of the dentin may not follow the expected patterns derived from studies on erupted teeth, and clinicians may need to adjust their restorative approaches accordingly. For instance, adhesive systems that perform well on erupted dentin may exhibit different bonding characteristics when applied to impacted dentin due to variations in surface energy, wettability, and collagen availability.

The limitations of this study should be acknowledged. The sample size, while adequate for detecting significant differences, was limited to a single institutional setting. Future studies with larger sample sizes and multiple tooth types would enhance the generalizability of the findings. The study employed an in vitro design, which, while allowing for controlled mechanical testing, does not fully replicate the complex biological and biomechanical environment of the oral cavity. The effects of aging, systemic conditions, and individual variations in dentin composition were not explored and warrant further investigation.

Future research should also investigate the correlation between tensile properties and other mechanical parameters, such as flexural strength and fracture toughness, to provide a more comprehensive understanding of dentin mechanics. Additionally, the influence of storage conditions and hydration status on tensile properties should be explored, as these factors are known to affect the mechanical behavior of dentin. The development of predictive models that correlate specific clinical parameters with dentin mechanical properties could ultimately guide personalized restorative approaches in clinical practice.

Conclusion

This comparative analytical investigation demonstrates that the dentin of completely impacted teeth possesses significantly higher tensile strength, maximum force tolerance, and tensile strain capacity compared to the dentin of fully erupted teeth. The ultimate tensile stress at break for impacted dentin was determined to be 6.21 MPa, compared to 2.79 MPa for erupted functional dentin. This marked variation highlights that prolonged exposure to the oral cavity, physical functional loading, and associated physiological aging processes reduce the overall tensile resilience and flexibility of erupted dentin, rendering it more brittle. The structural preservation of the organic collagen matrix in impacted teeth, combined with the absence of functional micro-fatigue and sclerotic changes, contributes to their superior mechanical performance.

Clinically, these structural insights emphasize the need to account for the specific origin and state of the dentinal substrate when designing, selecting, and applying advanced restorative and adhesive dental materials. Understanding that dentin properties vary significantly based on functional history can guide clinicians in optimizing restorative protocols, potentially improving the longevity and success of adhesive restorations. The findings of this study contribute to the growing body of knowledge on dentin mechanics and provide a foundation for future research aimed at developing material-specific restorative strategies that accommodate the inherent variability of dentin substrates.

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