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Research Article

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The Butterfly Effect: An Investigation of Hardness and Density of Sectioned Roots

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Abstract

Background: *The butterfly effect is an optical phenomenon seen in cross sections of roots. The teeth having butterfly effect had a higher density of dentinal tubules buccolingually than mesiodistally. Teeth with the butterfly effect may be weaker and thus more prone to vertical root fracture in the buccolingual direction.*

Aims and Objectives*: To investigate the hardness of dentin and density of the dentinal tubules in cross sections of roots exhibiting the butterfly effect.*

Materials and Methods*: 30 extracted single rooted teeth were selected and then divided into 3 groups of ten each. All the teeth were then cut into ten 1 mm thick cross sections and viewed under a light microscope. Teeth scored 1 or 2 according to presence of butterfly effect. The 2 teeth with lowest value were considered as control and 2 teeth from each group with highest value selected for further examination.Two adjacent cross sections were choose from the middle of the roots from each toothfor SEM to check density of dentinal tubules followed by Vickers test.*

Statistical Analysis*: It was done using student t test.*

Results*: The butterfly effect was seen at all levels in sectioned teeth. The dentine hardness observed more in mesio-distal than bucco-lingual direction and density found more in bucco-lingual direction.*

Conclusion*: Hardness and densities of dentinal tubules in sectioned roots were variable in bothdirections.*

Keywords: Butterfly, Density, Hardness dentinal tubules

Introduction

Dentin is a vital, hydrated composite material with structural components and properties that vary with location [1]. Detailed knowledge of dentine structure, and especially that of the dentinal tubules, is essential in order to understand dentine permeability, density, hardness and strength of dentine [2]. The butterfly effect is an optical phenomenon seen in some cross sections of tooth roots [3]. Decrease in number of dentinal tubules (i.e. density) gives a translucent appearance under light microscope [4].

Sclerosis of dentin plays an important role in density of dentinal tubules. Sclerosed dentin is more translucent than normal dentin [3,4]. Dentinal tubular sclerosis differs in buccolingual and mesiodistal directions, and this difference creates a characteristic butterfly shaped appearance. It is reported that teeth with the butterfly effect had a higher density of dentinal tubules buccolingually than mesiodistally, suggesting that this may affect hardness of dentin [5,6]. The aim of this study was to investigatethe hardness of dentin in mesiodistal and buccolingual cross sections of roots exhibiting the butterfly effect [7].

Subjects and Methods

Total of 30 single rooted freshly extracted human teeth of known age was collected.10 of which belonged to age group from 15-24 years (group I) other 10 from 25-44 years (groupII) and last 10 from 44 years and older (group III). Teeth with external root resorption, abnormal root anatomy, root fracture, root caries were excluded.

Roots were embedded in acrylic (DPI RR cold cure, New Delhi) and cut into 1-mm-thick cross sections. Each root from each group yielded 10 sections, which were marked to indicate orientation. These were viewed with a light microscope (Magnus MLX analytics, New Delhi) and given a score (Figure 1).

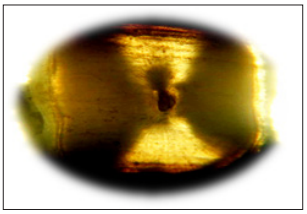


Figure 1: Butterfly effect under light microscope

Scoring Criteria

Score 1 or 2 were designated to the each section from 10 section of one sample and then the scores were added up to get a overall score with a minimum overall score of 10 and maximum of 20. A score of 1 represented no butterfly effect where the dentin had uniform colours, and 2 represented the butterfly effect with alternating shades of dentine. A score of 10represented a tooth with the effect totally absent and 20 represented tooth with effect present. From each age group, the 2 teeth with the highest overall score of 20 were selected for further examination. As controls, 2 teeth with a score of 10 (no effect) were selected [5].

Hardness Test

For each of the 8 teeth, 2 adjacent sections were chosen from the middle of the root to give 16 specimens [2]. To remove surface defects, sections were polished with silicon carbide paper (Ahmedallyhassanaly & Co. Chennai) of increasing grit and re-examined with the microscope to identify any remaining scratch lines and need for further polishing [7]. Each section was then indented with a square-based pyramid diamond indenter to determine vickers hardness (Shimadzu ltd tokyo, Japan.) The indenter was set to 0.1 kg (1N) load for 30 seconds [7]. Four indents were made per specimen on the mid mesial, mid-distal, mid-buccal, and mid-lingual aspects. Indents were made a consistent distance from the lumen, with the tip of the diamond facing the luminal space. Sections were then placed in 1% aqueous methylene blue dye and rinsed with water to increase visibility [7].

SEM Examination

SEM examination for density of dentinal tubules 8 teeth and 16 samples were scored as of earlier method. Samples were cut in mesiodistal and buccolingual direction (Figure 2).

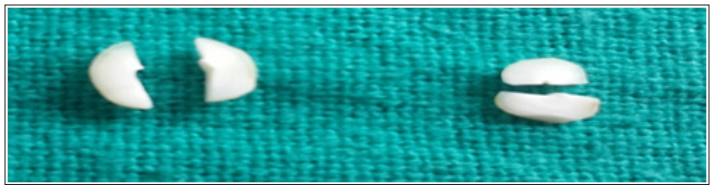


Figure 2: Cut samples in mesiodistal and buccolingual direction

To remove organic material and cutting debris, the specimen were placed in 3% sodium hypochloride (Vishal Dentocare Pvt.Ltd., India) for 5 min in ultrasonic bath followed by EDTA 17% for a further 5 min and then rinsed and stored in 0.9% saline (Marck Biosciences Ltd. India) until SEM analysis. Specimens were mounted with canal lumina upward. SEM images 850 X of the center of each canal lumen was taken (Figure 3 and 4).

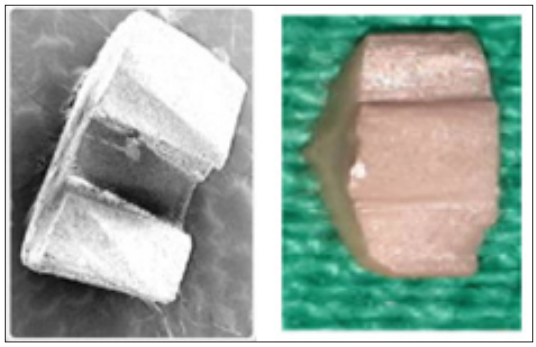
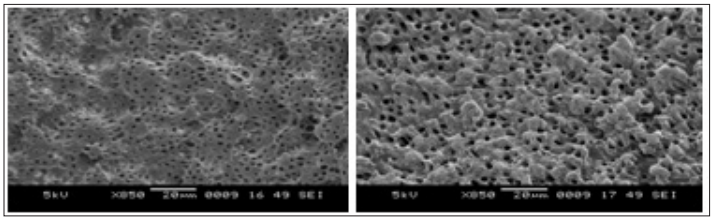


Figure 3: Specimen mounted on metal stub with canal lumina facing upward



a) Mesiodistal dentinal tubules **b) Buccolingual dentinal tubules**

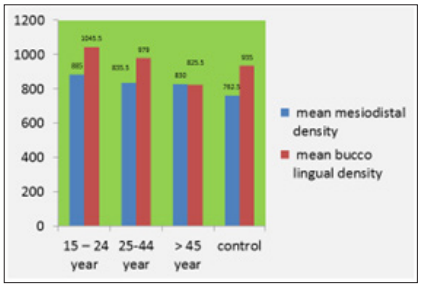
Figure 4: SEM images under 850X

Statistical Analysis

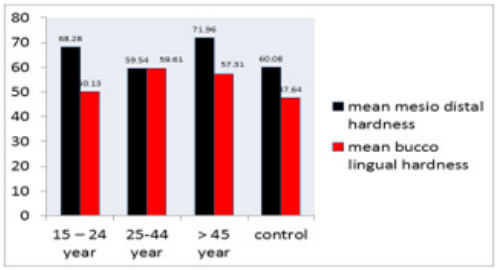
The data obtained from the present study was subjected to statistical analysis by using Student's unpaired t-test for using software SPSS 16# (SPSS Inc., Chicago, IL, USA).

Results

Hardness test reveal that the teeth with the butterfly effect were significantly higher in the mesiodistal surface and lowest in the buccolingual surface (Graph 1 and 2).



Graph 1: Density of dentinal tubules was higher in buccolingual direction than in mesiodistal



Graph 2: Hardness test reveal that the teeth with the butterfly effect were significantly higher in the mesiodistal surface and lowest in the buccolingual surface

SEM examination reveals the density of dentinal tubules was significantly higher in the root sections which were cut in buccolingual direction and lowest inmesiodistal.

On comparing mesio distal hardness of age 15-24 year, 25-44 year and > 45 year with control group, there was statistically no significant difference with p value > 0.05 i.e. (0.08), (0.43) and (0.10) respectively.

On Comparing bucco-lingual hardness of age 15-24 year, 25-44 year and > 45 year with control group, there was statistically significant difference with p value > 0.05 i.e. (0.05), (0.004) and (0.01) respectively.

On Comparing mesio distal density of age 15-24 year, 25-44 year and > 45 year with control group, there was statistically no significant difference with p value > 0.05 i.e. (0.34), (0.21) and (0.27) respectively.

On Comparing bucco-lingual density of age 15-24 year, 25-44 year and > 45 year with control group, there was statistically no significant difference with p value > 0.05 i.e. (0.25), (0.44) and (0.19) respectively.

Discussion

The aim of this study was to investigate the micro hardness of mesiodistal and buccolingual cross sections of roots of different ages exhibiting the butterfly effect. The butterfly effect was first photographed by Beust in 1931 as an optical phenomenon in some cross section of the tooth-root [3]. Vasiliades, et al. reported that the dentinal tubules sclerosis differs in the mesiodistal and buccolingual directions, noting a characteristic butterfly shape in transverse section of the roots caused by different shades of dentine [4]. The presence of dentinal tubules causes light to reflect and scatter. Butterfly effect is related to sclerosis, but it's appears that tubules density also plays a role in formation of butterfly appearance. Few research that has been conducted in the past suggested that teeth with the butterfly effect may be weaker and thus more prone to vertical root fracture in the buccolingual direction [6,7]. Studies have shown that higher densities of dentinal tubules correlate with lower tensile strengths of dentin [8,9]. The present investigation confirms that teeth with the effect have significantly lower hardness scores in the buccolingual direction, supporting the suggestion that they could be more susceptible to fracture.

The literature shows that vertical root fracture occurs more frequently in a buccolingual direction with craze lines or cracks on root sections more common buccolingually. Lertchirakarn, et al. investigated vertical root fracture patterns and found that the buccolingual dentin wall thickness is greater than that of the mesiodistal wall and that stresses are greater in the thickest part of the dentin [10]. Cracks propagate from the buccal or lingual surfaces more readily than mesial or distal. Buccolingual dentin wall thickness is greater than that mesiodistal wall and that stresses are greater in the thickest part of the dentin.

Butterfly effect is related to sclerosis, but it appears that tubule density also plays a role. The difference in the density in the tubules between the mesiodistal and buccolingual aspect regardless of the tooth age may have significant clinical implications.

A study of dye penetration in dentine tubules showed a distinctive barbell-shaped pattern, with more dye entering tubules in the buccolingual aspects. The permeability and butterfly like shape described were attributed to sclerosis, and this is coincides with our results. Considering the difference in tubules density and sclerosis in teeth having butterfly effect, it seems logical that radicular restorations on buccal and lingual surfaces may achieve better retention and longevity than those on proximal surfaces. Adhesion of sealers and penetration of some luting agents might be influenced by presence of fewer tubules mesiodistally as resin tags are required for micromechanical adhesion.

This potentially helps to explain vertical root fractures occurring more commonly in the buccolingual direction. This pattern is consistent with other clinical and experimental observations and is often regarded as counterintuitive. The fact that many tooth roots feature the butterfly effect and have higher densities of dentinal tubules and lower hardness scores in the buccolingual direction, regardless of dentin thickness, may help explain the unexpected pattern of vertical root fracture.

Canal shape and root morphology have been linked to vertical root fracture, with ovoid canals associated with higher stress concentration and a greater occurrence of cracks [11,12,13]. A limitation of our study is that canal shape and root morphology were not examined. Mechanical preparation of root canals is known to introduce craze lines and increase the risk of vertical root fracture. A smoothly rounded canal is favorable, eliminating stress concentration to decrease fracture susceptibility [13,14]. Thus, for teeth showing the butterfly effect, conservative root canal preparation and maintaining a circular canal shape may be very significant.

Root canal preparation, ultrasonic irrigation, Obturation techniques including lateral condensation of gutta-percha and post placement may produce unfavorable stresses and crack propagation in canals [10,12,15]. Studies investigating cracked teeth have found that there is a significant correlation between vertical root fracture and endodontically treated teeth. Canal shape and root morphology have been linked to vertical root fracture, with ovoid canals associated with higher stress concentration and a greater occurrence of cracks.

Cracks propagate from the buccolingual surfaces more readily than mesiodistal. This pattern is consistent with other clinical and experimental observations. Studies have shown that higher densities of dentinal tubules correlate with lower tensile strengths of dentin. Dentin micro hardness increases with increasing distance from the pulp. In this study the hardness was measured an equal distance from the canal lumen. Dentin is a hydrated substance, and although we attempted to maintain this, drying of specimens may have had an effect on hardness properties. The present study investigated teeth of different ages but did not consider the tooth type.

Von Arx, et al. examined the different characteristics of root sections and described the presence of ''frosted dentin'', which was more common in premolars and molars than in anterior teeth [11]. The clinical significance of our findings may therefore be more applicable to posterior teeth. Our investigation shows that teeth with the butterfly effect have lower hardness scores buccolingually than mesiodistally. This potentially helps to explain vertical root fractures occurring more commonly in the buccolingual direction [16,17,18]. In addition to micro hardness, there are other mechanical properties impacting on vertical root fractures. These include fracture toughness, flexural strength, fracture energy, and elasticity, factors that were not investigated in this study.

Conclusion

1. Root section with the butterfly effect has higher hardness scores on their mesial and distal surfaces, corresponding to the wings of the butterfly.
2. Density of dentinal tubules is more in buccolingual direction and lower inmesiodistal direction.
3. There may be clinical implication regarding dentine adhesive materials, sensitivity and an increased susceptibility to vertical root fracture in the buccolingual direction.

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