

The Occurrence of an Optical Phenomenon: “The Butterfly Effect” in Cross Section of Extracted Mandibular First Premolars

Acharya N,¹ Srii R,² Hasan R,³ Kafle D,⁴ Dahal S,⁵ Saito T⁶

¹Department of Conservative Dentistry and Endodontics,

Institute of Medicine,

Tribhuvan University Teaching Hospital,

Maharajgunj Medical Campus, Maharajgunj,

Kathmandu, Nepal.

²Department of Oral Pathology and Microbiology,

Coorg Institute of Dental Sciences,

KK Campus, Karnataka, India.

³Department of Oral Rehabilitation,

School of Dentistry, Health Science University of

Hokkaido, Hokkaido, Japan.

⁴Department of Orthodontics and Dentofacial

Orthodontics,

Kathmandu University School of Medical Sciences,

Dhulikhel Hospital, Kavre, Nepal.

⁵Department of Community Dentistry, Institute of

Medicine, Tribhuvan University Teaching Hospital,

Maharajgunj medical Campus, Maharajgunj,

Kathmandu, Nepal.

⁶Department of Clinical Cariology and

Endodontology, Health Science University of

Hokkaido, Hokkaido, Japan.

Corresponding Author

Nisha Acharya

Department of Conservative Dentistry and

Endodontics,

Institute of Medicine,

Tribhuvan University Teaching Hospital,

Maharajgunj Medical Campus, Maharajgunj,

Kathmandu, Nep.

E-mail: nishaacharya@iom.edu.np

Citation

Acharya N, Srii R, Hasan R, Kafle D, Dahal S, Saito T. The Occurrence of an Optical Phenomenon: “The Butterfly Effect” in Cross Section of Extracted Mandibular First Premolars. *Kathmandu Univ Med J.* 2025; 89(1):40-3.

ABSTRACT

Background

The butterfly effect is an optical phenomenon with endodontic and a restorative significance that can be seen in cross-sections of some of the tooth roots.

Objective

To investigate occurrence of butterfly effect in roots of extracted human mandibular first premolars and to determine differences in tubule density in mesio-distal and bucco-lingual direction of sections of root having butterfly effect.

Method

It was an prospective experimental study comprised of twenty single rooted extracted mandibular first premolars. Each tooth was divided into three sections: coronal, middle and apical third. Then, nine sections of each sample were taken, three from each section i.e., coronal, middle and apical third, hence making sample size of total 180. All the selected samples were ground into 1 mm thickness and examined under 20X magnification microscope. Five samples presenting with the butterfly effect were selected and prepared for Scanning Electron Microscope to evaluate the difference in density of dentinal tubules among mesio-distal and bucco-lingual direction. Mann Whitney U test was applied to find out the significance of butterfly effect among different sections. The data was entered in Microsoft excel sheet and transferred to Statistical Package for Social Sciences (SPSS) version 20 for statistical analysis. Ethical approval was obtained from Kathmandu University School of Medical Sciences institutional review committee (IRC No.:127/16).

Result

Butterfly effect was seen in 19.4% of sample. Apical sections had more occurrence rate (30%) followed by middle (23.3%), and coronal sections (5%). Female predilection (30%) for occurrence was seen. Under SEM, the samples with butterfly effect presented with higher median density (2349.32 number/mm²) of dentinal tubules in bucco-lingual section as compared to mesio-distal section (1208.23 number/mm²).

Conclusion

Butterfly effect was present in 19% of the samples. Butterfly effect is more seen on apical section of tooth. Female have more chance of having butterfly effect than male.

KEY WORDS

Butterfly effect, Dentinal tubules, Optical phenomenon, Tubular sclerosis, Vertical root fracture

INTRODUCTION

Beust in 1931 photographed by reflected light, an optical phenomenon on the root sections of tooth, which was later known as butterfly effect where sclerosed dentin appeared dark under transmitted light.¹ It is seen in some cross-sections of tooth roots due to differences in number of dentinal tubules and tubular sclerosis in mesio-distal (MD) and bucco-lingual (BL) directions. Two different shades of dentin are seen in transverse sections giving peculiar shape that corresponds to the wings of the butterfly.² Although mechanism behind dentin translucency is unclear; it is found that sclerosed dentin appears more translucent than normal dentin.³ More the dentinal tubules, more will be the scattering and refraction of light. Russell et al. reported that teeth with butterfly effect have higher density of dentinal tubules in BL than in MD direction.⁴ Thus, BL direction allows more amount of light to refract and scatter while the transmission of the light will be greater in MD direction resulting in translucent shade.⁵

The restorations done on sclerosed dentin with few dentinal tubules do not perform well. Teeth with butterfly effect may be weaker buccolingually than mesio-distally, forming the micro-cracks, thus supporting the suggestion that vertical root fracture (VRF) is more common in buccolingual direction.^{6,7} This may also make teeth more susceptible to hypersensitivity. This phenomenon might have some implication in endodontics, push out bond strength and microhardness of dentin too. Besides all these clinical implications, the literature on this optical phenomenon is however, deplete of adequate information. Hence, this study was conducted to determine the occurrence of this phenomenon and difference in tubule density in the sections that presents itself with the effect.

METHODS

The ethical approval for this experimental cross-sectional study was taken from the Kathmandu University School of Medical Sciences Ethical Review Committee (Protocol approval number: 127/16). This study was conducted from December 2019 to June 2020, in 20 single rooted extracted human mandibular first premolars from the patients of similar age group and of both genders, extracted for orthodontic reasons, from the Department of Orthodontics, Dhulikhel Hospital. Intact, non-carious, single rooted mandibular first premolars with fully formed roots and closed apices were included in the study. Carious teeth, teeth with fused or double roots, cracked/ fractured teeth, incompletely formed roots, root canal treated/ restored teeth and teeth longer or shorter than 20 and 16 mm respectively, were excluded from the study.

The samples were stored in 10% buffered formalin solution until further use. Then, the teeth were decoronated and radicular portion of each sample was then divided into

three sections: coronal, middle and apical third. After cross sections from each sample, nine sections were taken, three from each section i.e., coronal, middle and apical third, hence making total of 180 cross sectional samples (N=180) with diamond rotary discs (Dentsply, Maillefer). These were then divided into three groups: Coronal (C), Middle (M) and Apical (A) with 60 samples each. Then all the samples were grounded using Arkansas stone (Dentsply, Maillefer) to one mm thickness and mounted in a slide using DPX (Dibutyle phthalate xylene, Sigma-Aldrich).

After mounting, these sections were examined by two calibrated examiners, under the light microscope (Olympus CX22 LED, Tokyo, Japan) at 10 times magnification and scoring was given according to following criteria:

Score 1: Absence of two shades of dentin with uniform color (no butterfly effect) (Fig. 1).

Score 2: Presence of two different shades of dentin (presence of butterfly effect) (Fig. 2).

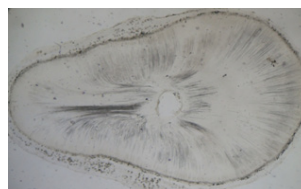


Figure 1. Absence of butterfly effect

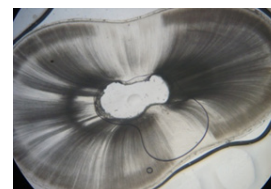


Figure 2. Presence of butterfly effect

The scores from each examiner were collected, summed and evaluated for the presence and absence of butterfly effect. The variations in the pattern of occurrence in male and female teeth were also considered. Data were then entered in Microsoft Excel Sheet and analyzed in SPSS software (Version 16). Frequency and percentage were calculated for descriptive analysis. Chi square test was done to determine the association of butterfly effect with different sexes and root sections. P value was set as < 0.05 for statistical significance.

Five samples from the apical sections presenting with the butterfly effect were selected and prepared for Scanning Electron Microscope (SEM, Hitachi, S-3500N) study to evaluate the difference in density of dentinal tubules among BL and MD direction (Fig. 3 and 4). Mann Whitney U Test was conducted to compare the tubules density among mesiodistal and buccolingual sections.

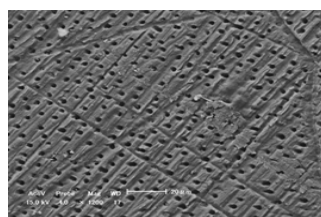


Figure 3. SEM image of BL cross section

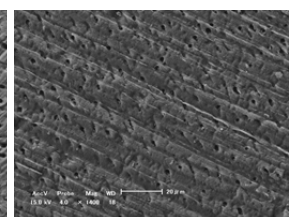


Figure 4. SEM Image of MD cross section

RESULTS

The descriptive statistics of this study is shown in table 1. Out of 180 root sections, butterfly effect was seen in 35 sections (19.4%). This phenomenon was found to be more common in females (n= 27) than in male (n= 8) sections.

Table 1. Presence of butterfly effect among different sexes and root sections

Characteristics	Number of participants (n)	Presence of butterfly effect n (%)	Absence of butterfly effect n (%)
Male	90	8(8.8%)	82 (91.2%)
Female	90	27(30%)	63(70%)
Total	180	35(19.4%)	145(80.6%)
Tooth Section			
Coronal	60	3(5%)	57(95%)
Middle	60	14(23.3%)	46(76.7%)
Apical	60	18(30%)	42(70%)

The comparison of butterfly effect among male and female sections showed that there was statistically significant difference between two sexes ($p < 0.001$, Table 2). This optical phenomenon was compared between three different sections. Overall, there was a significant difference seen among different sections. The coronal section was significantly different from middle as well as apical segment. However, middle segment and apical segment did not show any statistical significance. This phenomenon was found to be more common in apical sections followed by middle sections and was least observed in coronal sections (Table 2).

Table 2. Comparison of butterfly effect among different sexes and root sections

Comparison Group	Butterfly effect	No Butterfly effect	p-value
Male	8	82	<0.001 **
Female	27	63	
Coronal	3	57	0.007 **
Middle	14	46	
Coronal	3	57	0.001 **
Apical	18	42	
Middle	14	46	0.414
Apical	18	48	

** Statistically Significant at $P < 0.05$

The comparison of mesiodistal and buccolingual section's density of tubules is depicted in table 3. Significant difference in median density of tubules was seen with higher median density (2349.32 number/mm²) in buccolingual section as compared to the mesiodistal section (1208.23 number/mm², Table 3).

Table 3. Comparison of mesio-distal and bucco-lingual density of tubules

Section	Density in number/mm ² (mean±SD)	Median Density (number/mm ²)	p-value*
Mesio distal	1137.50±406.87	1208.23	0.047
Bucco lingual	6635±10223.32	2349.32	

*Mann Whitney U test

DISCUSSION

This in vitro study aimed to investigate the presence or absence of butterfly effect in three different sections of root and measure the differences in tubule density in BL and MD cross sections of the samples with butterfly effect. This phenomenon occurs due to the differences in dentin tubule density and sclerosis in mesiodistal and buccolingual direction of tooth roots.⁴ Researchers have found that teeth with butterfly effect may be weaker in buccolingual direction as the density of dentinal tubules is more with less intertubular dentin in that direction, hence making teeth more prone to VRF in the same directions.^{4,6,8} Also, in this study, similar pattern of occurrence of dentinal tubules was observed in the sections showing butterfly effect (Fig. 2). Butterfly effect has thus, more correlation with buccolingual fracture of root, which is more prone in endodontically treated teeth. Hence, endodontic treatment of teeth with butterfly effect can be challenging and clinician should be very careful while instrumenting buccolingual direction to prevent vigorous instrumentation.

Von Arx et al. observed frosted dentin more on premolars and molars compared to anterior teeth.⁹ This study found that 19.4% of samples prepared from premolars had butterfly effect. The clinical findings of this study would be therefore more significant in posterior teeth. In contrast to the study by Rao et al. the butterfly effect was not found throughout the length of the root in this study.⁸ Apical sections were found to have more occurrence rate (30%) followed by middle sections (23.3%), while coronal sections showed the least occurrence (5%). Hence, further research is needed to clarify this finding. Von Arx et al. also observed no difference between age groups in the occurrence of butterfly effect.⁹ The present study investigated the differences in gender, which showed 30% of female and 8% male samples had butterfly effect. However, the effect of age was not considered and samples from young age group were taken in this study.

Besides VRF, butterfly effect has other clinical significance also. Arslan et al. observed higher push out bond strength in the root sections exhibiting butterfly effect.¹⁰ Similarly, radicular restorations are more durable in buccolingual surface than on mesiodistal direction as sclerosis and obliteration of tubules have negative influence on resin tags formation.⁴ Moreover, the luting cements and resin based root canal sealers might have poor luting and sealing ability due to less number of tubules in mesiodistal

direction, hence compromising the final outcome in the teeth featuring the butterfly effect. Presence of butterfly effect may also render teeth more susceptible to cervical dentinal hypersensitivity due to the greater number of tubules in buccolingual direction.⁴

The lower the density of dentinal tubules, the higher is the tensile strength of the dentin.¹¹ In the present study, teeth with butterfly effect presented with more tubule density in buccolingual direction. Hence, teeth having this optical phenomenon have low tensile strength in buccolingual direction. This can render teeth more prone to microcracks leading to VRF in that direction.

The study has some limitations. The effect of age on the tubule density and sclerosis was not considered in the present study. Moreover, the clinical methods of predicting the presence of butterfly effect also needs to be formulated. Thus, further studies are recommended.

CONCLUSION

Within the limitations of this study, we found butterfly effect in 19.4% of samples with female predilection. This

effect was more common in apical third of root sections followed by middle and was seen least in coronal third. In the samples with butterfly effect under SEM, presented with higher tubule density in buccolingual direction compared to mesiodistal. This finding has a clinical significance regarding increased susceptibility of VRF in buccolingual direction. Moreover, the bonding of resin-based sealers, luting cements and proximal restorations might have poor adhesion in MD direction. With newer techniques and instruments, it is possible to prevent such consequences even in teeth with butterfly effect if one is conscious about this phenomenon and its pattern of occurrence. Thus, while performing endodontic treatment and restorative procedures, clinician should always consider these facts.

ACKNOWLEDGEMENTS

I would like to acknowledge Professor Dr. Takashi Saito, for his support, guidance, encouragement and permission to conduct SEM study in the lab at Department of Clinical Cariology and Endodontology, Health Science University of Hokkaido, Hokkaido, Japan.

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