EFFECTIVE HUMAN PULPAL BLOOD FLOW CHANGES DURING BRIEF INTRUSIVE FORCE APPLICATION AND CONTINUOUS ORTHODONTIC FORCE APPLICATION USING LASER DOPPLER FLOWMETRY

Authors:

Dr. Nagarajan Sadhasivam, MDS (Orthodontics)
Former Post graduate student,
Department of Orthodontics
Tamilnadu government dental college & Hospital
Chennai – 3
e-mail: naga_dentist@yahoo.co.in
ph: 097898 65082

Dr. S. Premkumar, MDS
Assistant professor,
Department of Orthodontics
Tamilnadu government dental college & Hospital
Chennai – 3

Dr. L. Muthusamy, MDS
Former HOD, Department of Orthodontics
Tamilnadu government dental college & Hospital
Chennai – 3

Abstract:

Aims: 1. To study the changes in human pulpal blood flow (PBF) during and after application of intrusive force for 4 minutes in right maxillary central using laser Doppler flowmeter. 2. To evaluate the effect on human pulpal blood flow after application of continuous orthodontic intrusive force for 72 hrs in right maxillary central incisor using laser Doppler flowmeter.

Material and methods:

Brief intrusive force application: Eight subjects (men; mean age = 19.6 yrs) had an intrusive force applied to a maxillary central incisor through lever system. A cast chrome cobalt coping was fabricated to fit over the incisor and thus provided a reproducible point of force application. Each subject participated in six testing sessions (0 gm, 5 gm, 50 gm, 100 gm, 250 gm force application and local anesthetic application). During each session, PBF was measured by laser Doppler flowmeter, 4 mins baseline period, then 4 min force application and then continuously measures next 12 mins. The last session local anesthetic with vasoconstrictor (epinephrine 1:100,000) was administrated in place of the force application to determine the ability of this experimental paradigm to detect reductions in PBF.

Continuous orthodontic force application: Seven subjects (men, mean age = 19.6 yrs) were selected and 2 OZ intrusive force applied to a maxillary central incisor using modified utility arch. PBF was measured before application of orthodontic force and after 72 hrs intrusive force application.

Results: There is no significant reduction in pulpal blood flow during and after the application of brief intrusive force for 4 mins. But there is definite amount of reduction in pulpal blood flow that occurs after application of 2 oz continuous orthodontic force for 3 days.

Conclusion: The study result indicates that there is a definite alteration in pulpal blood flow following continuous force application. But pulp does not affected by brief intrusive force.
INTRODUCTION

Orthodontic force has been hypothesized to alter pulpal blood flow (PBF) and thereby considered to cause pulpal tissue changes. Understanding the effects of orthodontic force on the pulp is of particular importance especially because it alters pulpal respiration rate, disruption of odontoblastic layer, pulpal obliteration of secondary dentin formation, root resorption and pulpal necrosis have all been associated with orthodontic treatment.

Of all the possible vectors of force that can be applied to the tooth during orthodontic treatment mechanotherapy, intrusion is thought to have the greatest impact on the apical region. The change in pulpal blood flow during brief intrusive force application is produced by compression of periapical blood vessels due to apical displacement of tooth. Strang\(^1\) makes the point quite clearly, “too powerful force might shut off the arterial blood supply and this causes a devitalization of the various elements in pulp”\(^9\).

An adequate blood supply to the dental pulp is essential to health of the tooth. Therefore, there have been a number of efforts to study the pulpal blood flow and factors that influence it. Initially studying the effects of pulpal blood flow were made by the following methods: Decalcification and india ink method\(^2\), Histological observation\(^3\), Pulp tissue respiration rate\(^4\), Direct microscopic observation\(^5\) and Fluorescent microsphere injection\(^6\) methods. These measurement methods have technical limitations that allow observation only once in each tooth examined. However, blood flow to the dental pulp is relatively inaccessible and apparently quite low. Consequently, it is difficult to obtain accurate pulpal blood flow measurement, partly owing to methodological difficulties in the small size of the tissue and its enclosure within rigid walls.

An introduction of Laser Doppler flowmeter (LDF) in dentistry, to access the pulpal blood flow, provides opportunity to test such type of hypothesis in a clinically meaningful situation. Since introduction of laser Doppler flowmeter (Riva, Ross and Benedek, 1972; Stern, 1975)\(^7\), which allows for non invasive, painless, quantitative and dynamic investigation of the perfusion of organs, various tissues have been explored in man and animals. It’s first used in human teeth was described by Gazelius et al.\(^8\) (1986). The technique is uncomplicated and the measurement process itself has no effect on the actual blood flow without causing any biological effects to the pulp. LDF is the only method to detect the pulpal blood flow changes continuously during orthodontic force application. It does not estimate absolute blood flow value, but it is able to monitor relative changes in a dynamic environment.

Therefore study of pulpal blood flow changes during orthodontic force application is of paramount importance, since long term health of the tooth could be affected by altered pulpal blood flow.

In this study, different magnitudes of intrusive force were applied to human maxillary right central incisor for each subject. Laser Doppler flowmeter was used to detect the changes in pulpal blood flow during and after application of brief intrusive force and continuous intrusive forces for 72 hrs.

Aims and Objectives

The aims and objectives of this study are

1. To study the changes in human pulpal blood flow after application of intrusive force for 4 minutes in right maxillary central using laser Doppler flowmeter.
2. To evaluate the effect on human pulpal blood flow after application of continuous orthodontic intrusive force for 72 hrs in right maxillary central incisor using laser Doppler flowmeter.

MATERIAL AND METHODS

Subjects

Eight subjects (men) between the ages of 18 and 22 years (mean=19.6 years) participated in this experiment. The subjects were selected such that they had unrestored vital maxillary right central incisor, no history of trauma, or recent orthodontic treatment. Volunteers were informed in writing about the purpose of the study and the procedure involved. The following were excluded from the study:

1. Nonvital teeth
2. Caries teeth
3. Restored teeth
4. Any previous orthodontic treatment
5. Any previous traumatic injuries
6. Gingivitis and Periodontitis
7. Cardiovascular diseases

Tooth responsiveness to external stimuli was evaluated by conventional electrical and thermal pulpal tests. Radiographs were taken to determine that the pulp chamber of the tooth was visible and that the periapical status of the tooth was normal.
Apparatus

A laser-Doppler flowmeter (Periflux PF, Perimed, Stockholm, Sweden) was used to assess pulpal blood flow. The light source is a 2 mW Helium-Neon laser within the flowmeter which produces red light with a wavelength of 632.8 nm that was sent along a flexible fiber-optic conductor inside the probe to the recording site. The probe contained three optic fibers (diameter 0.12 mm): one for transmitting and two for collecting light. Inside the round probe, each fibre was separated by approximately 0.7 mm. Light that contacted moving red blood cells were Doppler shifted and some of this backscattered light was returned to the flowmeter along a pair of optical fibers within the probe. The flowmeter then processed the amount of Doppler-shifted light that was returned and produced an output signal that was measured in volts.

A custom-made acrylic anchoring unit, which resembled a maxillary occlusal splint with no acrylic coverage of the incisor being tested, was fabricated for each subject. Two acrylic “arms” were extended labially and inferiorly to the central incisor. These two arms were used to support the ends of a stainless steel rod that served as the fulcrum of a lever. An aluminium lever arm moved around this fulcrum with the intraoral end contacting the central incisor and the extraoral arm extending into space. Different amounts of force could be applied to the incisor by suspending different amounts of weight from the extraoral end of the lever. The intraoral end of the lever had a contact with the incisor through a cast chromium cobalt coping that was fabricated for the central incisor that was receiving the intrusive force.

Custom made plastic splints of 3 mm thickness (Bioplast, Schen-Dental, Iserlohn, Germany) was vacuum formed for each subject using one maxillary cast. The main purpose of the plastic splint was to determine the baseline blood flow (not absolute) value and prevent the contamination from adjacent tissues.

Brief intrusive force application

Intrusive force was given by weight applied in the one end of the lever arm. The other end of the lever arm has a right angle contact with Cr-Co coping that allowed application of force along the long axis of tooth, which generated an intrusive force. Each session, intrusive force was changed by one of the five possible weights (0, 5, 50, 100 and 250 gm) that were applied to the end of the lever.

Each force application session began by having the subject sit quietly for a 3-minute rest period. The flexible bioplast splint (fig. 9) was placed and probe was placed in access hole. The probe was stabilized with both light body and putty polyvinylsiloxane material (Virtual, Ivoclar, Vivadent, Germany). First 4 minutes of blood flow data were collected before the placement of the rigid acrylic appliance that would be used to generate the intrusive forces.

Next, the acrylic splint and coping were placed and the lever was attached to the splint. Then the probe is placed in access hole prepared in Cr-Co coping and stabilized with polyvinylsiloxane impression material. Four minutes of baseline blood flow values were collected, and then one of five possible weights (0, 5, 50, 100 and 250 gm) was applied to the end of the lever (fig. 1). All subjects were tested with a different weight at each session and the order of weight application was determined randomly for each subject over the five test sessions. After 4 minutes of force application, the weight was carefully removed and blood flow values continued to be collected for an additional 12 minutes. Thus each session began with 4 minutes of PBF measurement with the bioplast splint, followed by 20 minutes of continuous PBF measurement (i.e., 4 minutes baseline, 4 minutes of force, 12 minutes after force) with the experimental apparatus in place. A photograph of the apparatus with a vertical reference line in the background was taken at each stage of data collection to enable the calculation of the angle between the lever and the true vertical (\(\theta\)).

During the final session, 1 ml of local anesthetic with vasoconstrictor (lidocaine with 1:100,000 epinephrine; Kostal pharma, AP, India) was administered in place of the force application. The pulpal blood flow was measured for next 16 mins. A minimum of 3 days separated each data-gathering session.

Continuous force application

The enamel surface of right maxillary central incisor (examined tooth) was prepared for bonding. Orthodontic brackets (0.022 × 0.028 inch, Roth prescription, Gemini, 3M Uniteck) were bonded to the labial surface of the right maxillary central incisor (examined tooth) and banding done in upper first molar with buccal tube attached and transpalatal arch was fabricated for each subject and cemented. Continuous orthodontic force was applied by means of a modified utility arch (fig. 2) for all examined (7) subjects. A modified utility arch wire (0.016 × 0.016 inch; Elgiloy, Morelli, Italy) was fabricated for each subject. It was 1-2 mm away from the mucosa and 4-5 mm short of the gingival margin. The utility arch was adjusted so that experimental tooth received an intrusive force of...
2 ounce (57 gm). The utility arch was activated either by an occlusally directed gable bend in the posterior portion of the arch wire or tip back bend in the molar segment. Amount of intrusive force was measured by using force measuring gauge (Dontrix, American orthodontics). The utility arch wire was afterwards engaged in the bracket with elastic modules. Before fixing the bracket onto the tooth, pulpal blood flow was measured for 4 minutes. After 3 days of continuous orthodontic force application period, brackets and bands were removed and pulpal blood flow was measured after placing bioplast splint on the tooth.

RESULTS

Brief intrusive force application

The ‘t’ test indicates that there was no significant difference between the mean PBF value obtained with the bioplast splint and the mean baseline value obtained with the experimental apparatus (p > 0.05) for each session for each subjects.

One factor repeated analysis of variance indicates no significant difference in baseline PBF values among the sessions (p > 0.05).

A repeated measures analysis of variance indicates that force levels had no statistically significant effect on PBF (p > 0.05). But among 40 sessions (all 8 subjects), only one session indicated significant reduction (p<0.05) and one session indicated significant increased PBF (p<0.01) (fig 3).

The ‘t’ test indicated that the PBF decreased significantly after administration of vasoconstrictor. The reductions in pulpal blood flow were measured and mean value is calculated. The percentage of reduction in pulpal blood flow from the baseline blood flow is calculated for every subject (fig 4). The overall mean (SD) percentage reduction for all subjects is calculated and found to be 40.16±9.62% of the mean (SD) (fig 5).

Continuous orthodontic force application

The ‘t’ test indicated significant reduction of PBF (p<0.01) after application of continuous orthodontic force for 72 hrs. After application of continuous force, pulpal blood flow was reduced by 31.19±11.89% of the mean (±SD) PBF value obtained before continuous force application (fig6 & 7).

DISCUSSION

To establish more complete biological basis of orthodontic therapy, it is important to study the reactions in pulp and pulpal blood flow. An adequate blood supply to the dental pulp is essential to health of the tooth. Pulpal blood flow determines the vitality of tooth. Though there are various types of orthodontic tooth movement, intrusion is most important factor affecting the pulpal blood flow. Because the main blood supply is through the apical foramen. During intrusive force application, the apical end of tooth gets closure to the apical alveolar bone, affecting the apical blood vessels and pulpal blood flow. Since main blood supply for the tooth via through the apical foramen, it is hypothesized that intrusive force could reduce the vascularity.

LDF measures the pulpal blood flow changes without any pain, continuously and non-invasively in the clinic. In this study right maxillary central incisor was used to evaluate pulpal blood flow changes during force application because of easy access and simplicity in applying force along the long axis of tooth. Odor et al.9 suggested that better signal specificity was obtained with 633 nm laser light than with 810 nm. It indicated that the 633 nm laser light had less penetration and less extensive spread.

Before starting each session, 4 minutes blood flow was measured with bioplast splint. The mean average was calculated, this is the mean pulpal blood flow for each subject. Then the experimental apparatus was placed and pulpal blood flow for 4 minutes was measured. It was compared and the results showed that no significant difference is occur.

There are several possible explanations for why the “strangulation” hypothesis of pulpal blood flow during heavy intrusive force application was not upheld. One possibility is that there was insufficient apical displacement of the tooth because of the short-term nature of the force application as well as the limited compressibility of the PDL due to presence of strong collagen fibers and hydraulic dampers system10,11,12,13.

If only 0.028 mm of apical tooth movement occurred and the average width of the PDL at the apex is between 0.18 and 0.21 mm, then the resulting reduction of less than 17% of the PDL space may be insufficient to compress the apical vasculature.

By using an animal model, Miura14 had suggested that compression of the periodontal membrane of one third or less does not alter its blood circulation. Furthermore, even quite heavy forces may not easily cause excessive apical tooth movement because of the mechanical properties of the PDL that resist displacement. Collagen fibers in the PDL are oriented to resist intrusive forces and remain rigid when force application is brief.
viscoelastic properties of the collagen fibers become more predominant and the tissue of the PDL will creep. In addition, a hydrodynamic damping system has been proposed that would resist rapid axial tooth movement in the short term.\\n
The study results showed that significant amount of pulpal blood flow reduction occurred when intrusive orthodontic force was given continuously for 72 hrs for all 7 subjects. Mean pulpal blood flow reduction is 32%, which should correlate with Y Sano et al.

W. Bunch, Butcher and Taylor, Anstendig et al., Hamersky et al. and Unsterseher et al. extensively studied changes in pulpal tissue during continuous intrusive force application using histological methods. All the results showed significant reduction in the pulpal blood flow. The results of this study also correlated with these findings.

It may be explained that during continuous intrusive force application periodontal membrane cannot withstand the force to resists apical movement. So when excessive intrusive force is given, there is definite amount of reduction of pulpal blood flow.

In this study significant reduction of pulpal blood flow was observed after administration of a vasoconstrictor. It provides evidence that this experimental method was capable of detecting changes in pulpal blood flow. Vongsavan and Matthews said that if laser Doppler flowmeter detected changes in pulpal blood flow after administration of epinephrine, it can be used for experimental research.

CONCLUSION

This study suggests that PBF in a human maxillary central incisor is significantly altered by the application of continuous orthodontic intrusive force (72 hrs) but no significant reduction of pulpal blood flow when brief intrusive force (4 mins) was given. The significant alteration in the pulpal blood flow during continuous orthodontic force indicates that the microvascular system of dental pulp may be compromised during orthodontic intrusion of teeth. But brief intrusive force did not produced alterations in microvascular system of dental pulp.

REFERENCES:

5. Guevara M and McClugage S. Effects of intrusive forces upon the microvasculature of the dental pulp. Angle Orthod 1980; 50(2); 129-134.


**Fig 1:** shows pulpal blood measurement during 100 gm intrusive force application.

**Fig 2:** Shows continuous intrusive force application by modified utility arch.

**Fig 3:** Table shows mean PBF values during and after effective intrusive force application and local anesthetic administration

<table>
<thead>
<tr>
<th>Mean grams of intrusive force (SD)</th>
<th>Weight (gm) added during force application</th>
<th>Weight (gm) added during force</th>
<th>Bioplast splint (4mins)</th>
<th>Baseline (0-4 mins)</th>
<th>Force (4-8 mins)</th>
<th>Post force (8-20 mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>40.03(10.23)</td>
<td>40.38(10.12)</td>
<td>41.24(10.06)</td>
<td>40.67(09.89)</td>
<td></td>
</tr>
<tr>
<td>73.50(1.48)</td>
<td>5</td>
<td>41.09(10.74)</td>
<td>41.59(10.65)</td>
<td>41.52(11.33)</td>
<td>41.58(11.12)</td>
<td></td>
</tr>
<tr>
<td>463.23(2.53)</td>
<td>50</td>
<td>40.71(10.90)</td>
<td>40.69(11.36)</td>
<td>40.27(10.73)</td>
<td>40.37(11.44)</td>
<td></td>
</tr>
<tr>
<td>893.53(4.25)</td>
<td>100</td>
<td>41.53(10.65)</td>
<td>41.06(11.27)</td>
<td>41.67(10.58)</td>
<td>41.52(10.42)</td>
<td></td>
</tr>
<tr>
<td>2153.98(13.79)</td>
<td>250</td>
<td>40.71(10.84)</td>
<td>40.78(10.82)</td>
<td>42.86(10.90)</td>
<td>40.84(10.73)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0(epinephrine)</td>
<td>42.06(11.68)</td>
<td>41.68(11.19)</td>
<td>33.45(10.99)</td>
<td>23.35(09.21)</td>
<td></td>
</tr>
</tbody>
</table>
**Fig 4:** Comparison of PBF values (mV) during various levels of intrusive force and local anesthetic administration.

**Fig 5:** Comparison of PBF (mV) before and after vasoconstrictor administration.

**Fig 6:** Table shows analysis of mean PBF (mV) before and after continuous orthodontic force application by 't' test.

<table>
<thead>
<tr>
<th>subjects</th>
<th>Mean PBF (SE)</th>
<th>Base line</th>
<th>After 72hrs</th>
<th>t value</th>
<th>P value</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>53.50(.29)</td>
<td>42.75(.25)</td>
<td>28.15</td>
<td>0</td>
<td>20.09</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>43.50(.29)</td>
<td>31.75(.25)</td>
<td>30.77</td>
<td>0</td>
<td>27.01</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>36.50(.29)</td>
<td>24.25(.25)</td>
<td>32.08</td>
<td>0</td>
<td>33.56</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>41.00(.41)</td>
<td>29.25(.25)</td>
<td>24.54</td>
<td>0</td>
<td>28.65</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>19.00(.41)</td>
<td>8.25(.25)</td>
<td>22.46</td>
<td>0</td>
<td>56.57</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>34.75(.48)</td>
<td>25.25(.25)</td>
<td>17.59</td>
<td>0</td>
<td>27.33</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>44.75(.48)</td>
<td>33.50(.29)</td>
<td>20.02</td>
<td>0</td>
<td>25.13</td>
</tr>
</tbody>
</table>

Mean reduction PBF = 31.19 ± 11.89%

**Fig 7:** Comparison of PBF (mV) before and after continuous force application.