

Changes in Gingival Blood Flow during Orthodontic Treatment

Research Article

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Abstract: The aim of the study was to investigate the changes in gingival blood flow due to orthodontic forces. Eleven volunteers, with the maxillary canine in an ectopic position were tested. A Laser Doppler Flowmeter (LDF) with a gingival probe was used, registering both the blood flow and temperature of the gingivae. After baseline measurement, a fixed orthodontic appliance was bonded. Measurements were repeated monthly, after activation of the appliance. The study lasted 6 months. The baseline value was 338.7 ± 201.56 P.U. [Perfusion Unit (mean $\pm$ S.D.)] which decreased to 218.9 ± 74.83 P.U. ($p < 0.05$) after two months and the final value of 363.9 ± 194.86 P.U. was not significantly different from that initially ($p > 0.5$). The results showed that application of a force of 75 g resulted in a decrease in gingival blood flow up to 50%, but this returned to previous values after a few months. The study supports this measurement technique as a useful tool for monitoring gingival blood flow in long-term studies as well.

Keywords: Laser Doppler • Gingival blood flow • Orthodontics

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1. Introduction

The basic aim of orthodontic treatment is to move teeth by causing bone remodelling. The required bone remodeling occurs as a result of forces below those that can not be tolerated by the periodontium. Schwarz's data suggests that the applied force cannot be greater than 20-25 g per tooth, a value corresponding with that of the blood pressure in the capillary system [1]. Other studies confirmed that forces bigger than 20-25 g could damage the periodontium [2-4]. However, in many cases orthodontists use much stronger forces (100 – 150 g) with fixed appliances without any periodontal damage in many cases [5].

The non-invasive estimation of gingival blood flow has been very difficult for a long time. All of the previous techniques used to measure gingival blood flow suffer from drawbacks. Vital microscopy required cumbersome optical equipment and only a small sample of capillaries can be observed [6-8]. To estimate red blood cell velocity with cinematography, one individual cells must be traced in successive film frames past blood vessel landmarks [8]. Microsphere infusion permitted flow measurements on one occasion and cannot be used in humans [9]. Radioisotope clearance methods were similarly limited and also suffer from difficulties of data analysis [10]. Impedance plethysmography was applicable in human studies, but requires electrodes to touch the tissue being monitored [11]. Heat clearance indirectly measures

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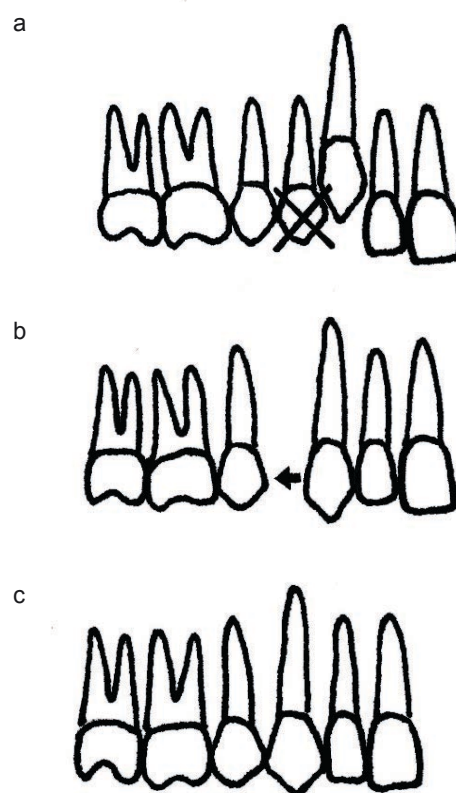
blood flow and the heat itself may alter flow [12]. So a noninvasive and continuous technique was needed for measurement of gingival blood flow in human subjects. Studies on the changes in gingival blood flow due to gingivitis or changes in pulp circulation were published earlier [13–17]. In these studies many factors were measured: the effects of temperature, pressure, occlusal force, inflammation, administration of local anaesthetic containing vasoconstrictor and sympathetic stimulant agents. (These experiments started with blood-flow mapping of oral tissues.) The method used had many disadvantages including high cost and non-reproducibility. There were many technical problems and many of the methods were not suitable for use in humans. Due to its anatomical structure, the attached gingiva seems to be suitable for in vivo measurements with the Laser Doppler Flowmeter (LDF). This method was firstly used by Gazelius and his co-workers, who studied blood flow to the pulp [18].

The microcirculation can be monitored semiquantitatively with LDF. This method was developed to assess blood flow in intact microvascular systems such as those in the retina, gut mesentery, renal cortex, and the skin, but it was also suitable for study of blood flow in oral tissues also [19,20].

The instrument has many advantages: non-invasive, harmless, simple, reliable, rapid, and well tolerated by patients. This method gives results immediately and continuously over a time period. In dental diagnostics a further advantage of LDF is that blood flow can be measured not only in directly accessible soft tissues (e.g.: gingiva), but in dental pulp as well, in permanent and primary, unharmed and traumatized teeth also, and in healthy and cleft palate patients as well [7,12–17,21–25]. There are also data on changes in the blood flow of oral tissues of orthodontic patients. The influence of external loads on the blood flow in the dental pulp of human teeth treated with fixed and removable orthodontic appliances was evaluated in short-time studies [26,27]. The effect of brief and continuous intrusive forces on human pulpal blood flow of upper left central incisors was also measured with LDF [28,29].

Although several studies deal with pulpal blood flow, there has been no publication on longitudinal changes in the gingival blood flow of orthodontic patients treated with fixed appliances. The aim of this study was to measure the microcirculation in the gingiva and its changes with time during orthodontic treatment of ectopic canines with fixed appliances for a six-month period, using LDF as a well established method and if possible, draw conclusions from the observations.

Figure 1. The treatment planning for patients participating in the study. a.) First upper premolar was extracted to ensure a place for the canine, one month before starting the orthodontic treatment. b.) The canine was moved to its correct position with distal tipping. c.) The result at the end of the orthodontic treatment.



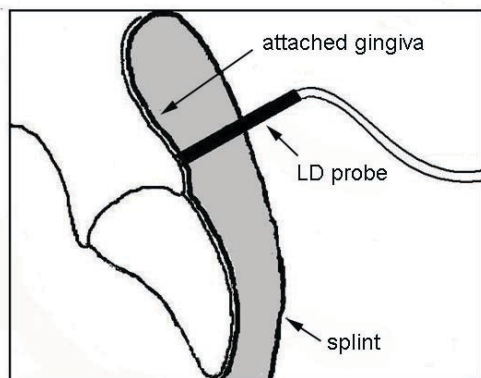
2. Material and Methods

Altogether eleven volunteers (two boys and nine girls) with ages ranging from 15 to 22 years (18 ± 2.36 , mean $\pm$ S.D.) participated in the study. The patients were students, with no systemic diseases or medication, and were non-smokers. They had complete permanent dentitions, with clinically healthy periodontium and good oral hygiene. All of them had the maxillary left canine in a vestibular ectopic position requiring orthodontic treatment. During the study they did not need or receive any dental care apart from the orthodontic treatment. Informed consent was obtained prior to measurements and data collection.

This study was approved by the Ethical Committees of Semmelweis Medical University and the University of Debrecen.

The treatment planning for all patients demanded extraction of the ipsilateral first upper premolar. The canine was then moved to its normal position with distal tipping during the treatment (Figure 1). The probe was

Figure 2. Position of the fibre optic probe above the gingival surface. The stabilizing splint ensured a constant place for the tip of the probe and fixed the relationship between the upper and lower arches.



located over the canine, which was to be moved. The extraction of the first premolar was performed and after complete wound healing, there was a minimum of one month before starting the orthodontic treatment. It can be concluded that it influences adjacent canine blood flow. Under the phase of distal tipping of the canine, we changed the splint monthly to ensure the same place of the probe, above the canine.

After orthodontic examination of patients and enrollment into the study, brackets and molar bands (Dentaurum, Roth type) were cemented (NO-Mix Orthodontic Bonding System, Dentaurum, Germany and Vitremer glass ionomer cement 3M, USA). Thereafter a special impression was made with silicone putty impression material (Zetaplus – Zhermack) to serve as a stabilizing splint for the tip of the fiber optic probe and also to fix the relationship between the upper and lower arches. The impression putty material was applied high into the upper vestibulum (above the upper teeth) to make sure that there was enough space for the tip of the probe and that it did not touch the borders of the upper and lower arches. The splint did not prevent movement of the canine and other teeth but ensured that all measurements were always made at the same point on the gingiva. Holes (approximately 4 mm) in diameter were made into the silicone putty material to stabilize the probe and ensure its same position at each measurement (Figure 2). The procedure was repeated on every occasion of orthodontic activation according to the new position of the canine.

Baseline measurements were done before beginning the active orthodontic treatment with wires. The splint was placed between the two arches and the baseline reading was made after one minute (stabilization time). Then the patients were monitored for at least 20 minutes. During the measurements subjects were placed in

a supine position, with the head and the heart on the same plane. Measurements were repeated after placing and activating the wires. Readings were completed within one hour after activation of the appliance. The long time of the repeated measure did not allow taking observations on the contra lateral side, so the first measurement was used as control in this study.

The PERIMED System 4000 with double channels LDF (Perimed AB, Jarfalla, Sweden) was used, after calibration, and the probe model PF 472 (with tip 1.7 mm in diameter) was used. The blood flow of the attached gingiva was measured above the upper left canine, 5 mm from the free gingival margin. The depth of the measurement was 1 mm. The time constant was 0.4 s and the range was 0-1000 P.U. The temperature of the skin on the neck was monitored (in °C) continuously by contact thermometer (Peritemp) and the laser curve was recorded simultaneously. Both measurements were performed on each person. Changes of the skin temperature during measurements could be due to changes of the systemic blood flow.

Measurements lasted from 20 to 60 minutes. The study lasted for 6 months with repeated-measures monthly. For the activation procedures 75 g force was applied per tooth, which was controlled every time with a dynamometer (Dentaurum No 040711, Newtown, PA).

Data were analyzed with an advanced data acquisition program used to store, retrieve and analyze data from LDF measurements (Perisoft 5.0). Results are given as mean values $\pm$ S.D. The significance of differences was determined by a paired t-test. Differences with $p < 0.05$ were considered to be statistically significant.

3. Results

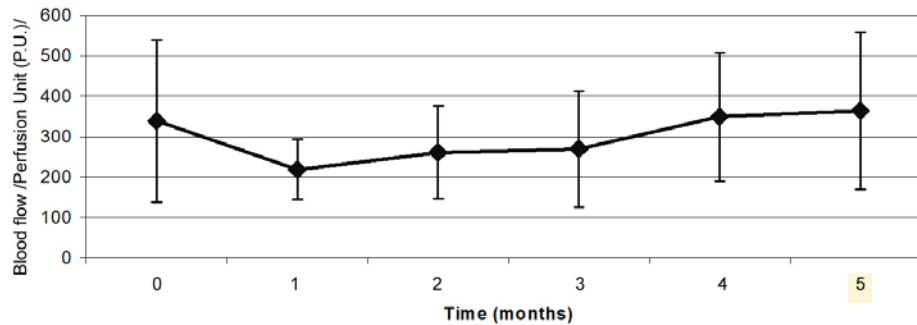
Mean values expressed as Perfusion Unit (P.U.) of the blood flow measurements obtained during the treatment over six months are summarized in Table 1.

In most of the subjects the first values (338.7 ± 201.56 (P.U. $\pm$ S.D.)) decreased after 1 month (218.9 ± 74.83 (P.U. $\pm$ S.D.)) ($p < 0.05$) and then increased gradually up to the sixth month (363.9 ± 194.86 P.U.) (Figure 3). In three patients, namely the “D”, “J” and “K”, the flow increased after the first reading and then it decreased to the end of the treatment. No statistically significant change was recorded between the first and last values ($p > 0.5$).

The temperature of the skin [mean $37.2 \pm 0.6^\circ\text{C}$ (mean $\pm$ S.D.)] was monitored continuously and remained constant during all measurements, so the reason of the changing of the gingival blood flow could not be a systemic event.

Table 1. The results of blood flow measurement for each patient.

	Age (year)	1. Measure	2. Measure	3. Measure	4. Measure	5. Measure	6. Measure
Patient "A"	20.00						
Mean(P.U.)		318.40	138.78	127.12	244.62	345.60	357.49
S.D.		40.09	24.69	14.55	44.32	23.54	69.63
Time(min)		40.00	45.00	50.00	40.00	55.00	40.00
Patient "B"	16.00						
Mean(P.U.)		414.16	208.13	243.88	412.21	427.42	446.69
S.D.		26.98	70.05	68.12	27.63	86.31	88.24
Time(min)		40.00	45.00	50.00	40.00	45.00	55.00
Patient "C"	18.00						
Mean(P.U.)		352.27	164.18	120.47	263.30	345.97	307.57
S.D.		76.42	48.88	33.1	72.31	37.67	30.64
Time(min)		35.00	50.00	55.00	25.00	60.00	52.00
Patient "D"	19.00						
Mean(P.U.)		122.89	322.13	379.77	162.47	232.69	113.14
S.D.		60.75	79.42	54.88	61.5	69.18	41.24
Time(min)		50.00	55.00	50.00	30.00	60.00	60.00
Patient "E"	22.00						
Mean(P.U.)		805.83	328.56	450.52	644.94	721.66	766.72
S.D.		121.89	71.44	133.49	123.31	87.76	74.02
Time(min)		45.00	40.00	35.00	30.00	40.00	50.00
Patient "F"	18.00						
Mean(P.U.)		408.64	329.05	343.44	183.85	229.86	327.13
S.D.		274.93	37.6	99.9	77.48	48.02	40.42
Time(min)		50.00	50.00	20.00	60.00	30.00	50.00
Patient "G"	17.00						
Mean(P.U.)		289.50	129.55	119.72	178.87	210.36	266.44
S.D.		62.12	30.44	24.07	36.61	48.03	45.7
Time(min)		80.00	45.00	65.00	40.00	65.00	60.00
Patient "H"	17.00						
Mean(P.U.)		278.82	176.55	200.19	220.90	270.92	298.07
S.D.		43.28	35.44	47.61	43.92	46.29	28.01
Time(min)		45.00	50.00	45.00	55.00	60.00	65.00
Patient "I"	22.00						
Mean(P.U.)		500.60	190.11	271.35	278.38	501.45	661.87
S.D.		107.19	45.8	52.47	53.04	107.16	70.69
Time(min)		35.00	40.00	55.00	50.00	55.00	55.00
Patient "J"	16.00						
Mean (P.U.)		108.55	231.73	236.32	181.05	383.75	275.37
S.D.		63.98	51.31	70.87	27.84	272.10	21.00
Time(min)		45.00	45.00	45.00	40.00	60.00	50.00
Patient "K"	15.00						
Mean (P.U.)		126.32	189.31	378.88	193.35	178.87	183.16
S.D.		51.28	53.5	54.07	31.68	36.61	36.37
Time(min)		35.00	40.00	40.00	40.00	50.00	50.00
Mean	18.18	338.73	218.92	261.06	269.45	349.87	363.97
S.D.	2.359	201.56	74.83	115.35	143.19	158.58	194.86

Figure 3. Changes in gingival blood flow during orthodontic treatment based on the results of 11 patients (P.U., mean $\pm$ S.D., respectively).

4. Discussion

The reaction of the periodontium to orthodontic forces has been investigated by several researchers, but data have originated mainly from animal studies [4,23,30]. Our aim was to investigate non-invasively how the blood flow of the gingiva changes under orthodontic forces in humans in a longitudinal study. Clinically the orthodontic tooth movement consists of three phases: initial tooth displacement, delay without any movement and linear tooth movement [31]. From histological studies it is well known that if a force is applied on the crown of a tooth, characteristic changes can be observed in the periodontium: pressure and tension zones appear at the apical and other areas, with extended vascularisation and destruction of the collagen fibres. By applying an orthodontic force, the signal transduction pathways which lead to bone remodeling are quite complex and not totally understood [32]. However, the induction of tooth movement can be well understood by a theoretical model describing four different stages: matrix strain and fluid flow, cell strain, cell activation and differentiation, and remodelling [33]. Above a threshold orthodontic force, after activation of ion-channels, stress receptors, cytoskeleton reorganization, etc., osteoclasts appear on the surface of the alveolar bone in the pressure zone and initiate bone resorption. Simultaneously bone apposition occurs in the tension zone with “bodily” tooth movement (non tipping), similar changes occur except that the pressure and tension zones extend from apex to crown, along the root length and their localization depends on the direction of the force. Accordingly, blood flow is also altered in the different parts of the periodontium [34].

The stress caused by tooth movement is distributed in the periodontium and affects the blood circulation. Yamaguchi et al. (1991) have shown that the same degree of force results in varying changes in blood flow among subjects [4]. In another study of gingival tissue decreased blood flow had a higher positive correlation

with tooth displacement than with the degree of force [35]. It was noticed at nearly all five readings that tooth displacement has a closer relationship to decreased blood flow than to the degree of force and could be the determining factor for the vascular reactions.

This work initially examined the changes of the blood flow of the periodontium during orthodontic treatment with fixed orthodontic appliances, in a follow-up study by LDF. The values obtained in human subjects resemble those found by Sasano et al. in 1995 in animal experiments [36]. They found that after exerting a direct force on teeth, blood flow increased on the pressure side and decreased on the tension side. It is in agreement with the findings that showed that orthodontic intrusion of teeth caused a reduction (on the tension side) in the pulpal blood flow and in the periodontal microcirculation, although no effects were determined on the gingival tissues during the application of orthodontic extrusion [2,29,37,38].

In most of our patients the blood flow decreased in the cervical part of the periodontium (tension zone). The mean values obtained at the base reading decreased after two or three measurements, then progressively approached the first values. As the measurements were made after the activation of the fixed appliance (within one hour), it appeared that tissues responded to the great force with a decrease in blood flow and then showed progressive adaptation, so these changes were reversible. Another study also showed similar reversible changes in the pulp tissue after radical molar intrusion, during the retention period [39].

Values for patient “E” differed from the other results. Despite a lack of evidence of clinical signs of inflammation, high values were noticed at all six readings. At the same time the general tendency was the same: blood flow first decreased and then returned to the initial value. The higher gingiva flow rate could be an individual variation or a subclinical gingivitis might be occurring. It was demonstrated that laser Doppler flow readings (LDFRs) are positively correlated with the degree of gingival

inflammation. LDFRs values were significantly higher in patients with experimental gingivitis than in healthy subjects [40]. Krishnan and coworkers also reported that orthodontic appliances can evoke local soft-tissue responses in many ways [41]. It was also demonstrated that orthodontic extrusion had no negative effects on the gingival tissues around the canines.

The results on three patients (“D”, “J”, “K”) were contrary: their blood flow increased during the treatment. This could be due to the extension of pressure and tension zones along the roots, the direction of the forces depending on the axis of the teeth. Since the axes of ectopic teeth (roots) were not exactly the same before the treatment (because it was not possible to standardize this factor), different force vectors could have occurred at the measuring point- where the probe was located – in spite of the constant force applied. Thus the dimension of pressure and tension zones was probably not the same in every case.

LDF gave us a modern, non-invasive method for the investigations. Blood flow in the gingiva has already been examined with anatomical and histological methods, but the functional response of different morphological structures is still not known well.

The modulator role of baseline blood flow in the vasomotor responses of pulpal blood flow was shown [42]. Further investigations are needed on how the baseline level can affect the gingival blood values during orthodontic treatment.

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The Laser Doppler Flowmetry (LDF) is a useful method for assessing the microcirculation of numerous human oral tissues, such as tongue, buccal mucosa, gingival and pulp [43]. Generally, in constant circumstances (applied forces, measurement time, and the same time interval after activation of a fixed appliance) the values of gingival blood flow in most cases show a similar tendency to those of earlier human studies. However, there can be other (individual?) changes in patients treated with fixed orthodontic appliances. It is published in some cases that a daily routine, such as toothbrushing can cause a shortlived change in the gingival microcirculation [44]. The stress caused by orthodontic forces in the periodontal tissues may vary with the direction of applied force and displacement of the tooth.

The LDF method seems to be a useful tool for monitoring the blood flow in long-term studies in orthodontic patients using different treatment methods as well as in different clinical situations in dentistry in which the blood flow of the periodontium may be changed. Measurement of gingival blood flow with LDF allows the changes in the blood flow of the periodontium to be checked throughout the whole orthodontic treatment and avoids the application of harmful forces. Identification of the factors causing changes in blood flow of healthy or damaged periodontal tissues requires further investigation.

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