Effect of orthodontic forces on blood flow in human gingiva

By Kazunori Yamaguchi, DDS, PhD; Ram S. Nanda, DDS, MS, PhD; Terushige Kawata, DDS, PhD

Orthodontic force brings about tooth mobility in the alveolar socket as the periodontal and gingival tissues are compressed or stretched.[1,2] Consequently, blood flow in these tissues changes according to the applied force or mobility of teeth.[3-5] Changes in blood flow can lead to alterations in vascular permeability,[6,7] resulting in the remodeling of alveolar bone and the rearrangement of connective tissue.[8,9]

Optimal force for orthodontic tooth movement has been studied. Oppenheim[10] and Reitan[1] reported the optimal force levels based on the capillary blood pressure in the periodontal membrane. Similarly, Gaengler and Merte[5] showed the function of the angioarchitecture of the oral tissues to the applied force using vital microscopy, and Kondo[3] found changes in periodontal blood flow in cats caused by varying forces using the plethysmography. Baab et al.[11] studied gingival blood flow using Laser flowmetry, and described the difference in the blood flow in the various gingival tissue types and changes caused by thermal stimuli. However, there has been little evidence to confirm the relationship between the blood flow change and application of force, because of difficulties in measuring the microcirculation in human tissue, especially continuously and non-invasively.[3,4,12-14] Recently, a non-invasive tool capable of measuring microcirculation, Laser Doppler flowmetry, has been applied to many kinds of tissue.[15-21]

This study was designed to measure changes in blood flow in human gingiva using Laser Doppler flowmetry as a function of the degree of orthodontic force.

Basic principles of Laser Doppler flowmetry

A helium-neon laser has a constant, stable wave length of 632 nm. When the focused beam

Abstract

The relationship of gingival blood flow to the magnitude and duration of applied force was studied in humans using Laser Doppler flowmetry. The sample consisted of five adult volunteers with interdental space between their maxillary central incisors. The labial surface of each central incisor was bonded with a buccal tube and a spring force was applied to close the space. The forces applied were 50 g, 80 g, 120 g, and 250 g. Each force was applied for 30 seconds, 60 seconds, 90 seconds, 5 minutes, and 10 minutes. The blood flow signals were recorded continuously using a pen recorder. Measurements indicated that blood flow was negatively correlated to the amount of force applied. The duration of reactive hyperemia was positively correlated to the duration of force. Laser Doppler flowmetry measures blood flow in superficial periodontal tissues. Yet, the relationship of blood flow changes to the magnitude and duration of orthodontic force suggests that measurements of gingival blood flow may provide a means of estimating physiologic orthodontic forces.

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Key Words

Gingival blood flow • Orthodontic force • Laser Doppler flowmeter • Reactive hyperemia

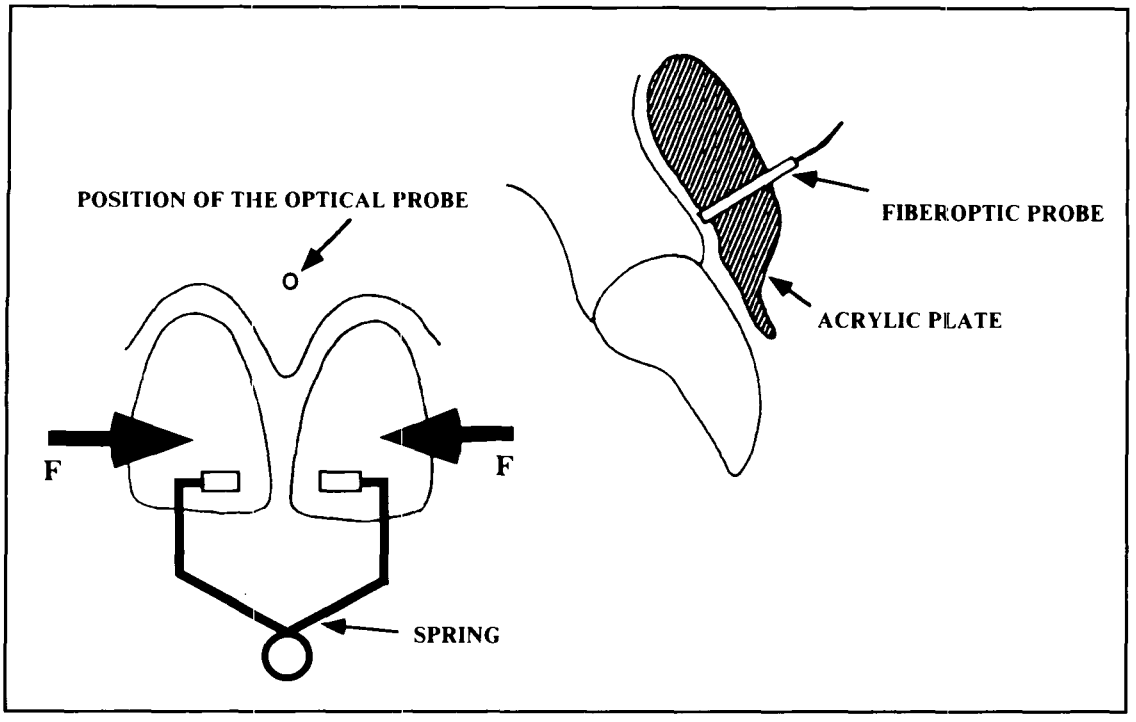

Figure 1
Application of force and positioning of the fiber-optic probe. The plate was made to hold the probe at a right angle to the upper border of the attached gingiva. The tip of the probe was positioned 0.5 mm from the gingival mucosal membrane. Buccal tubes were bonded on the labial surface of the maxillary central incisors, and springs were hooked on the tubes to close the interdental space.

Figure 1

is scattered in static tissue, there is no change in frequency of reflected light. However, its frequency does change according to the Doppler principle when scattered by moving red blood cells. Therefore, changes in frequency reflect the velocity and number of the moving red blood cells.[18,22-24] In this flowmeter, the blood flow is represented as the blood flow velocity, multiplied by the volume of the red blood cells[23-25] in a hemisphere of 1.0 mm radius.[21,25,26]

Material and methods

Five healthy male volunteers with interdental space between their maxillary central incisors were selected. Their ages ranged from 20 to 32 years, and they were free from any clinical signs of gingival inflammation. A plastic plate was designed to stabilize the optical probe while measuring. It was custom made for each subject and was designed to cover the premolars, the anterior teeth and the vestibular region (Figure 1). The plate was trimmed in the area adjacent to the anterior teeth and the vestibular region, thus preventing the plate from making any contact with the oral mucosal membrane and incisors. A hole 2.6 mm in diameter was opened at a right angle to the lower border of the attached gingiva in the midline of the maxillary arch. The tip of the probe was inserted into the hole and held with a self-curing acrylic (Figure 1). The probe was positioned 0.5 mm from the mucosal surface. A Laser Doppler flowmeter (ALF 2100, Advance Co., Tokyo, Japan) was used for all measurements.[25] The flowmeter's time constant was set at 0.1 and 1.0 seconds, and the signals of blood flow were continuously recorded by pen recorder (302121, Yokogawa Co. of America, GA). With the plate in position, each subject was laid in a supine position so that the heart and head were in the same positional plane. After monitoring the patient with the flowmeter in position for 10 minutes, measurements were started in a quiet room with room temperature between 20 and 25°C.

External stimuli

1. Pressure on both infra-orbital fossae

To identify the blood supply of the infra-orbital artery to the maxillary gingival tissue, the blood flow changes in the attached gingiva due to the direct pressure on the infra-orbital fossae were measured.

2. Deep breathing

Each subject was asked to take a deep breath for a short time, and the blood flow in the attached gingiva and finger tip was measured.

3. Localized pressure with probe on the gingival tissue

The fiberoptic probe was inserted into the hole until the tip of the probe made contact with the gingival tissue. It was then released.

4. Application of orthodontic forces

a. Application of force

Buccal tubes for orthodontic treatment were bonded to the labial surface of the maxillary central incisors, and four levels of contractive force, 50 g, 80 g, 120 g and 250 g were applied with springs (Figure 1). The springs were constructed with 0.5 mm, 0.6 mm, 0.7 mm and 0.8 mm orthodontic round wires respectively. Each

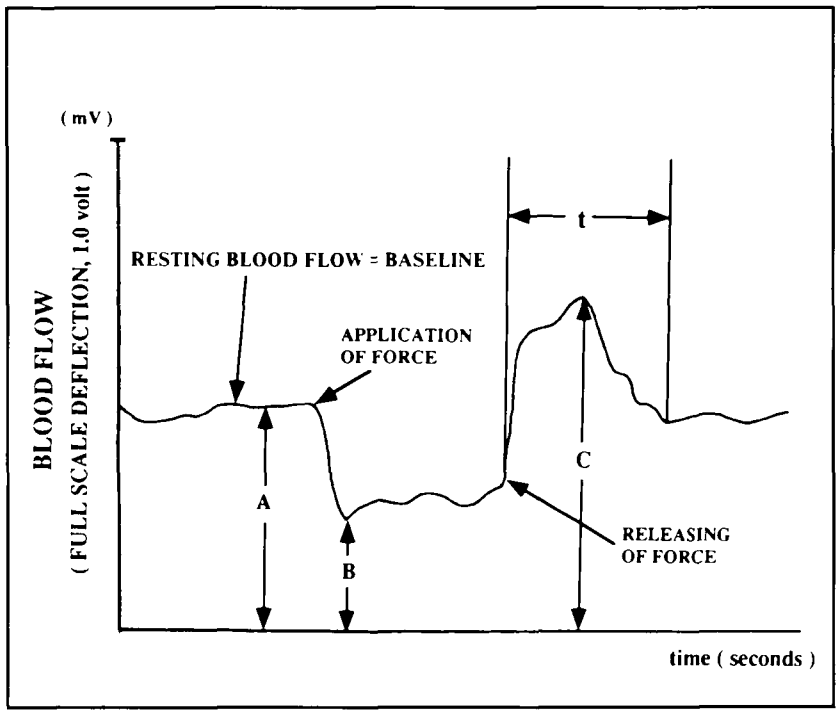

Figure 2

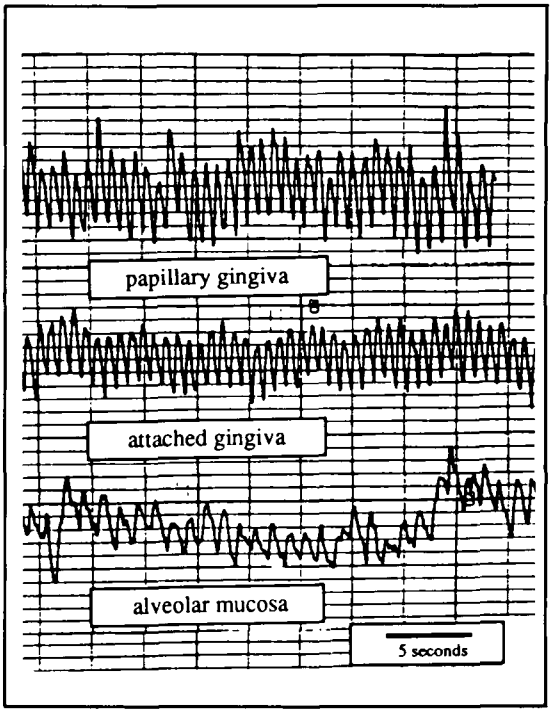

Figure 3

force was applied for 30 seconds, 60 seconds, 90 seconds, 5 and 10 minutes.

b. Evaluation of gingival blood flow

As indicated in Figure 2, the changes of blood flow before, during and after application of forces were measured. "A" represents the baseline blood blow during the resting period, while "B" represents the maximum decreased blood flow caused by the applied force. "C" is the maximum increased blood flow after releasing force, and "t" (duration of the reactive hyperemia) is the recovery time to resting level. Each change was also represented relative to the corresponding blood flow during the resting period, i.e., B/A x 100 is the percentage of the decreased flow to the flow during resting period, and C/A x 100 (the magnitude of reactive hyperemia) is the percentage of the maximum increased flow to the flow during resting period after discontinuing the force. All measurements were repeated two times at the same position of the probe in each subject. Reproducibility of blood flow measurements for repeated recordings was examined using paired *t*-test and Pearson's correlation coefficient, and variability of measurements for each subject was examined using one factor repeated analysis of the variance (ANOVA). The relationships between the blood flow changes and the magnitude and duration of force were tested using Pearson's coefficient.

Results

Blood flow in resting period

In the 1.0 second time constant, a wave pattern synchronized with the heartbeat, and a wave pattern not synchronized with the heartbeat were observed. The non-synchronized pattern was continuous and rhythmic, and corresponded to the slower vasomotion frequency. In the 0.1 second time constant (Figure 3), the wave pattern in the papillary and attached gingiva were well synchronized with the heartbeat, while those in the alveolar mucosal membrane were less well synchronized.

Effects of deep breathing

Figure 4 shows the blood flow recording in the attached gingiva and finger tip while breathing deeply. Blood flow in both tissues decreased for a short time during inspiration. The drop in blood flow (relative to the flow during the resting period) was approximately 50% to 70% for the finger tip, and 10% to 30% for the attached gingiva.

Effects of localized pressure on both infra-orbital fossae

When the localized pressure with the thumb was exerted on the infra-orbital fossae, the blood flow in the attached gingiva decreased slightly (Figure 5).

Effects of localized pressure with a fiberscopic probe

Blood flow in the attached gingiva decreased rapidly and drastically after applying pressure with the probe on the mucosal surface. On releasing the pressure, an increase of blood flow was observed which dissipated in approximately 30 to 40 seconds. The effect of the degree of force could not be identified because the force was not standardized.

Figure 2
Estimation of the blood flow changes in the gingival tissue. A: blood flow during the resting period, B: maximum decreased blood flow caused by the application of force, C: maximum increased blood flow after releasing force, t: recovery time to the resting level (the duration of the reactive hyperemia).

Figure 3
Recording of the blood flow during the resting period in the three types of gingival tissues. The time constant was set at 0.1 second. The waves in the papillary and attached gingiva were well synchronized with the heartbeat. The waves in the alveolar mucosa, however, were less synchronized.

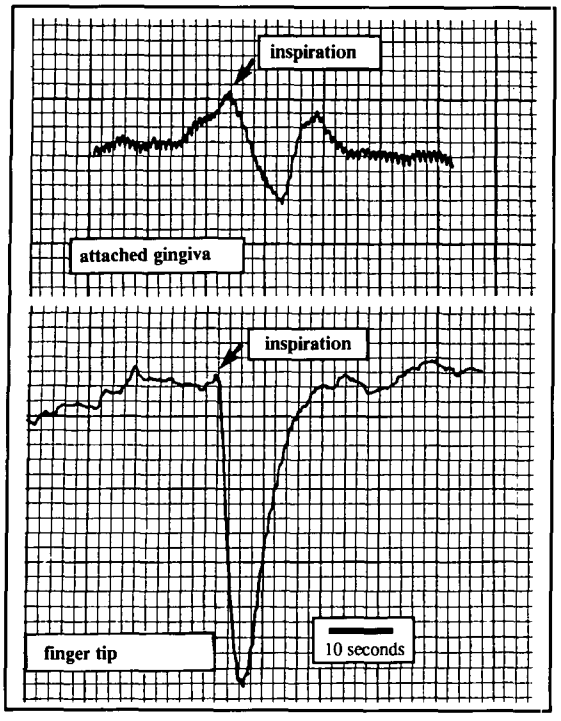

Figure 4

Figure 4
Changes of the blood flow due to deep breathing. Blood flow in both tissues decreased during inspiration, however, the reduction of blood flow was more remarkable in the finger tip than in the attached gingiva.

Table 1
Paired *t*-test and correlation coefficients between the first and second recordings.

Measurement parameters	paired *t*-test p	r
Blood flow during resting period (A)	0.4525	0.951
Decreased blood flow (B)	0.6473	0.959
Percentage of the decreased blood flow (B/A x 100)	0.1399	0.849
Increased blood flow (C)	0.3652	0.875
Percentage of the increased blood flow (C/A x 100)	0.6712	0.750
Duration of the increased blood flow (t)	0.1399	0.830
Mean		0.866

Table 2
Comparison of the blood flow measurements among each subject using one factor repeated analysis of variance.

Degree of force	Duration of force	Decreased blood flow (B)	Percentage of decreased blood flow (B/A x 100)	Increased blood flow (C)	Percentage of increased blood flow (C/A x 100)	Duration of increased blood flow (t)
50g	30sec	0.0260*	0.1104	0.0397*	0.9695	0.3171
	60sec	0.0011**	0.0473*	0.0023**	0.1990	0.0573
	120sec	0.0002***	0.0001***	0.0147*	0.0089**	0.2530
80g	30sec	0.0001***	0.0154*	0.0144*	0.0951	0.0685
	60sec	0.0029**	0.3477	0.0017**	0.0140*	0.7631
	120sec	0.1711	0.0350*	0.0014**	0.6640	0.0651
120g	30sec	0.0448*	0.0124*	0.0180*	0.1876	0.4904
	60sec	0.0175*	0.7751	0.0524	0.0930	0.6653
	120sec	0.0285	0.0824	0.0345*	0.0068**	0.5138
250g	30sec	0.0017	0.7751	0.0524	0.0930	0.6653
	60sec	0.0013**	0.0734	0.0165*	0.0094**	0.4293
	120sec	0.0003***	0.0399*	0.0002***	0.0308*	0.2009

*p<0.05; **p<0.01; ***p<0.001

Application of orthodontic force

1) Reproducibility and variability

The reproducibility for repeated recordings of the blood flow was examined by taking two recordings at different times and using a paired *t*-test (Table 1). There was no significant difference between the two groups of recordings of the blood flow during resting period (A), decreased blood flow (B), percentage of the decreased blood flow (B/A x 100), increased blood flow (C), percentage of the increased blood flow (C/A x 100), and duration of the increased blood flow (t). The first recording was highly correlated (mean r = 0.866) to the second recording. The variability for the measurements among the subjects was examined using one factor repeated ANOVA (Table 2). There was a significant difference ($p < 0.011$) in blood flow during resting period among the subjects. Although there were significant differences among the subjects for each measurement, significance of difference was lower in the blood flow repre-

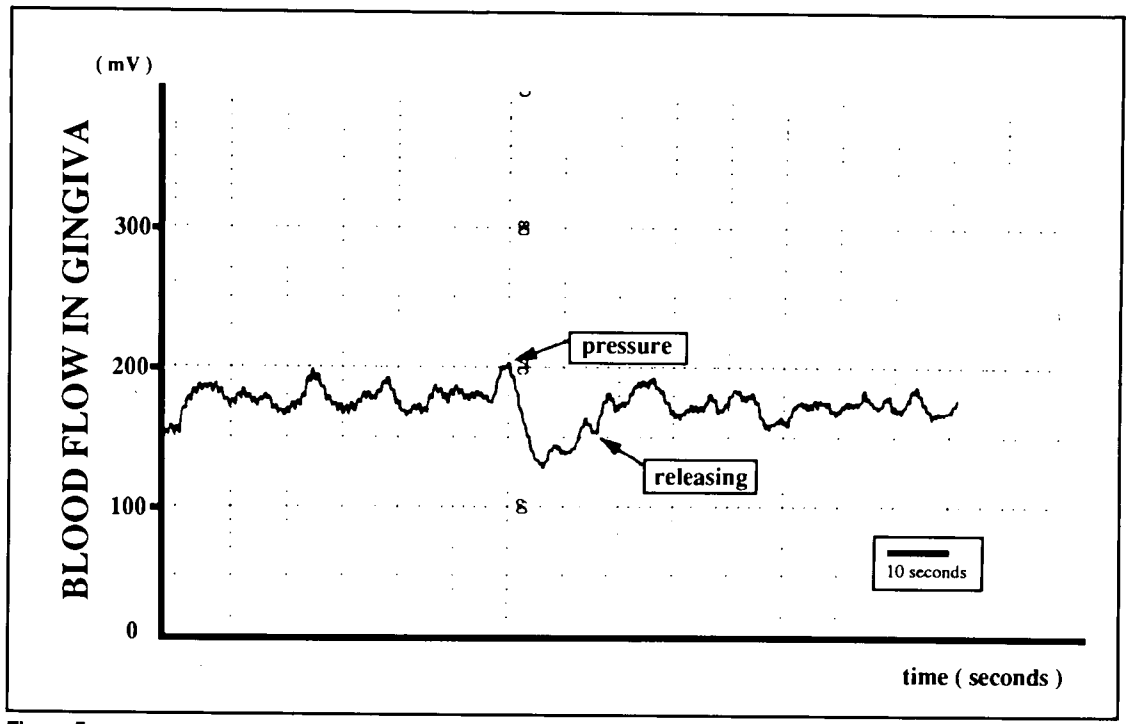

Figure 5

Figure 5
Change of the gingival blood flow due to digital compression pressure on both the infra-orbital fossae. Bilateral disturbance of the infra-orbital arteries slightly reduced the blood flow in the attached gingiva.

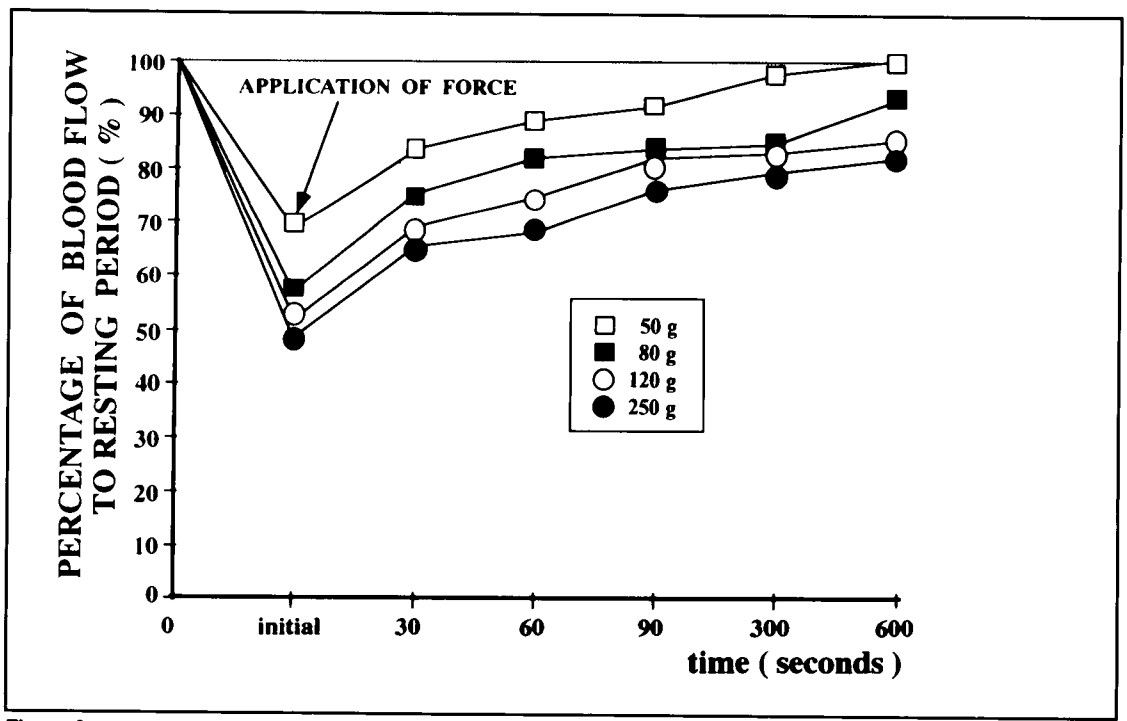

Figure 6

Figure 6
Changes of the blood flow in the attached gingiva during the continuous application of orthodontic force. The gingival blood flow decreased instantly when the force was applied, and recovered gradually toward the resting level. However, the decreased blood flow due to the heavier force (120g and 250g) did not recover completely by 5 or 10 minutes.

sented as the percentage over the resting period (B/A x 100 and C/A x 100) as compared to the blood flow (B and C). There was no significant difference for the duration of the increased blood flow (t) among the subjects.

2) Blood flow changes due to the applied force

The mean resting gingival blood flow was 207.2 mV ± 53.3. Mean gingival blood flow (B) decreased to 175.7 mV ± 34.2, 110.7 mV ± 29.4, 90.3 mV ± 15.6, 105.3 mV ± 42.7 by 50g, 80g, 120g, and 250g respectively. The percentage of gingival blood flow (B/A x 100) decreased to 70.1% ± 6.1, 57.5% ± 5.8, 52.6% ± 5.4, 49.1% ± 5.0 by 50g, 80g, 120g, and 250g of force respectively. The decrease in blood flow represented as a percentage of the resting level (B/A x 100) was negatively correlated (r = -0.625) to the degree of force. However, the correlation coefficient of the decreased blood flow (B) was lower (r = -0.374) than that of the percentage of the resting level.

Figure 7
Relationships of the magnitude of the reactive hyperemia (increased blood flow) to the degree of forces and the duration of application of forces.
■ : 50 g of force,
□ : 80 g of force,
▨ : 120 g of force,
▩ : 250 g of force.
The blood flow (C) decreased according to the duration of force. The percentage of increased blood flow (C/A x 100) increased according to the degree of force.

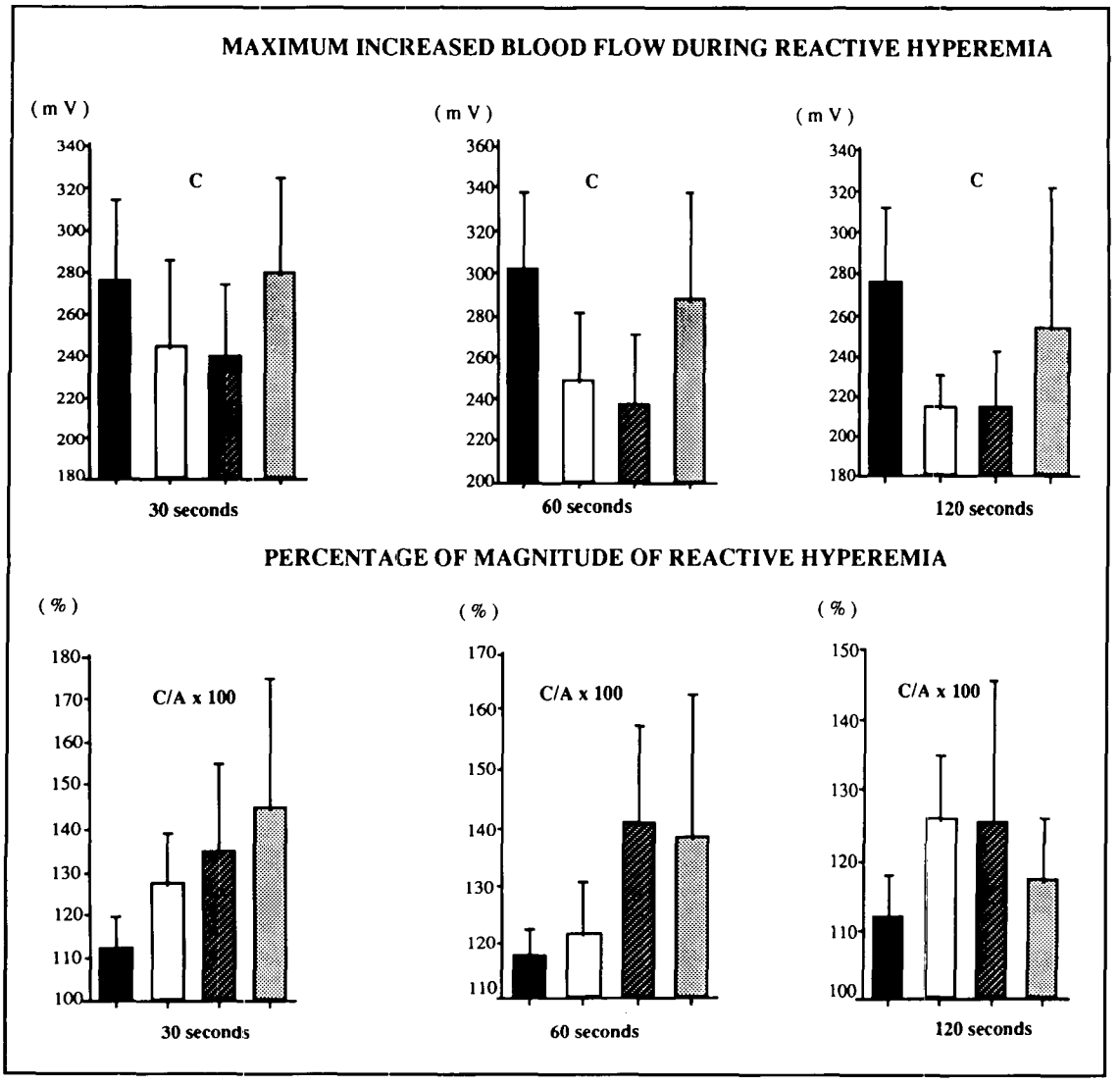

Figure 7

Figure 8
Relationships of the duration of increased blood flow to the degree of forces and the duration of application of forces. The duration of increased blood flow (t) increased corresponding to the degree of force and the duration of application of force.

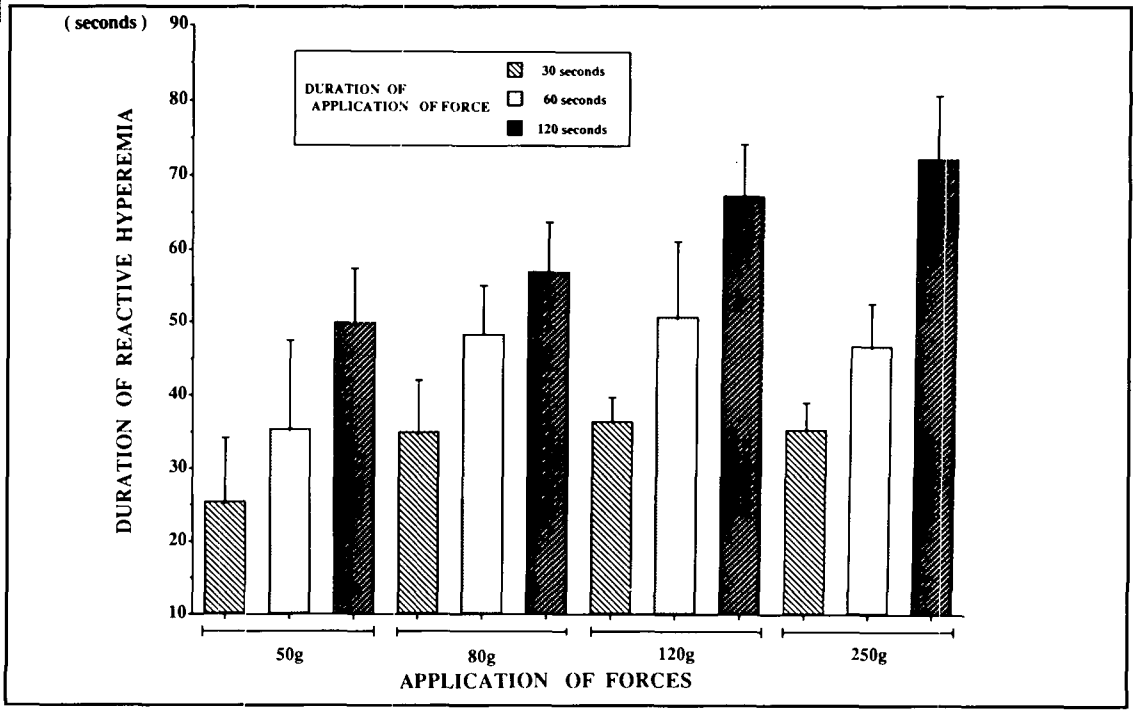

Figure 8

Table 3 and Figure 6 show the changes of the blood flow during application of force. The decreased gingival blood flow gradually recovered to the blood flow during resting period. The blood flow by 50g of force recovered over 90% of resting blood flow level after 90 seconds, however, the decreased blood flow caused by 80g, 120g and 250g of forces did not recover after 10 minutes.

3) Reactive hyperemia (transient increased blood flow) after discontinuing force

a. Magnitude of the reactive hyperemia versus the degree of force and decreased blood flow

The decreased blood flow recovered and increased above the resting level after releasing the applied force. Figure 7 shows the means and standard deviations of the maximum increased blood flow (C) after releasing force and percentage of increased blood flow over resting level (C/A x 100). The relationship between the increased blood flow (C) and the degree of force was not clear ($r = 0.071$) as shown in Figure 7, upper. However, the percentage of the blood flow due to reactive hyperemia (C/A x 100) increased corresponding to the degree of force (Figure 7, lower). The percentage over resting level (C/A x 100) was mildly correlated to the degree of force ($r = 0.324$) and also to the B/A ($r = 0.639$). On the other hand, figures of Pearson's coefficient of the percentage of increased blood flow (C/A x 100) and increased blood flow (C) to the duration of force were -0.222 and -0.232 respectively.

b. Duration of the reactive hyperemia

Figure 8 shows means and standard deviations for the duration of the increased blood flow. The duration of the reactive hyperemia increased corresponding to the degree of force and the duration of the application of force ($r = 0.385$ and 0.757).

Table 3
Means and standard deviations of the gingival blood flow during continuous application of orthdontic force.

	50g mean (%)	80g mean (%)	120g mean (%)	250g mean (%)
initial	70.1 ± 6.1	57.5 ± 5.8	52.6 ± 5.4	49.1 ± 5.0
30sec	84.5 ± 8.6	76.2 ± 13.6	70.0 ± 10.5	66.1 ± 8.6
60sec	89.9 ± 9.9	82.7 ± 12.4	75.4 ± 13.1	68.6 ± 12.6
90sec	92.4 ± 12.4	84.5 ± 12.7	82.6 ± 8.1	76.6 ± 9.2
5min	98.3 ± 13.7	85.3 ± 9.4	83.7 ± 10.8	80.2 ± 10.6
10min	100.0 ± 0.0	93.6 ± 12.1	86.4 ± 12.1	82.6 ± 9.9

Discussion

The infra-orbital artery, a branch from the maxillary artery, descends from the infra-orbital fossae along the anterior surface of the maxillary bone, and supplies maxillary gingival tissue, bilaterally. This was verified by the decreased blood flow in gingival tissue corresponding to the pressure on both infra-orbital fossae. According to Forsslund[27] and Nuki et al.,[28] small vessels, precapillary arterioles, and postcapillary venules are widely distributed in the attached gingiva. Reactions in the microcirculatory system caused by localized pressure or stimuli are considered to be initiated at small vessels.[29,30]

Vasomotor reflexes

The effect of vasomotor reflex and vasomotion in the skin tissue has been reported by several authors.[19,27,31] The vasomotor reflexes are governed by sympathetic nerves,[19,31-33] local autoregulatory mechanisms[34] and angioarchitecture of microcirculatory system. Vasomotion is caused by the activity of microvascular smooth muscles and is dependent on temperature.[19,26] The decrease of blood flow due to deep breathing has been shown by using plethysmography.[19,33,35] Low et al.[19] investigated vasomotor reflexes in the skin tissue using Laser Doppler flowmetry and reported that the blood flow decreased to 44% during deep breathing. In our study the percentage of decreased blood flow in the finger tip was 10% to 30% as compared to 50% to 70% in the attached gingiva. These differences were interpreted to be due to varying functional responses of the two tissues to external stimuli.

Application of force and reduction of blood flow in the gingiva

Kurashima[36] examined tooth displacement caused by orthodontic force and indicated the viscoelastic properties of the periodontal membrane. He showed that initial displacement reached a maximum in 2 or 3 seconds. In our study, initial reduction of blood flow reached a maximum in 2 or 3 seconds. This indicates that the mobility of teeth instantly induces a stress in the gingival tissue and affects the gingival blood flow. Baab et al.[11] reported on the gingival blood flow in humans using Laser Doppler flowmetry, and indicated that blood flow in free gingiva decreased (less in the attached gingiva) with a biting force on the mandibular incisor

(degree of force was not given). The biting force may exert a vertical force to intrude mandibular incisors, and the stress in the attached gingiva may be less than that induced by mesio-distal mobility of teeth. In our study, the force was applied to the maxillary central incisors to close the interdental space, and the decrease of blood flow was correlated ($r = -0.625$) to the degree of force. Therefore, blood flow changes in the gingival tissue will vary with direction of force as well as the degree of force.

In the periodontal ligament, blood flow decreases gradually with applied force for a certain period.[3] This indicates that the microcirculatory system in the periodontal membrane is a semi-open system.[3,5,36] Gaengler and Merte[5] reported the effects of application of force on periodontal blood circulation using vital microscopy. They theorized that reversible changes of blood flow during application of force may be dependent on the degree and duration (continuous and intermittent) of force. They also stated that the blood circulation of the gingival tissue is independent of the blood flow in the periodontal membrane. In our study, the reversibility of the gingival blood flow during application of force was dependent upon the degree of force. During force application, blood flow in the attached gingiva gradually recovered to the resting level. This recovery may be attributed to an indirect blood flow from adjacent capillary loops and networks of vessels because the microcirculatory system in the gingival tissue is open.[5,27,37] However, the decreased blood flow caused by heavier forces was not recovered even after 10 minutes. This means that large stress may be distributed extensively in the gingival tissue, and may affect gingival blood flow for an extended period of time.

Reactive hyperemia after releasing force

Reactive hyperemia (RH), a transient increase of blood flow following interruption of blood flow, is well known in cardiac vessels.[38] It is induced by the vasomotor function or autoregulation and locally produced chemical mediators.[26,27,39-41] However, this reaction in the skin autonomic function is not common.[38] Bache and Ederstrom[40] reported reactive hyperemia following occlusion of an artery in dog's legs. They stated that the reactive hyperemia was prolonged with the duration of the occlusion of the arteries. Hiyama,[42] in observing the oral tissue of dogs, showed the relative contributions of prostaglandins and oxygen pressure in the tissue to the occurrence of reactive hyperemia. Locally produced chemical mediators, such as histamine, bradykinin,[43-45] and PGE_2[46] contribute to the reactive hyperemia. Additionally, these mediators can play important roles in the alteration of the vascular wall,[6,30,31] that is, increased permeability, vasodilation, and opening the junction of each reticular cell. Iida[6] and Yamaguchi et al.[7] studied vascular permeability in the periodontal membrane and palatal soft tissue. They showed two distinct phases in the increased vascular permeability caused by tooth movement. These inflammatory reactions possibly induce the infiltration of cells, such as leukocytes, mast cells, macrophages and fibroblasts which play a role in the remodeling and rearrangement of hard and soft tissues. Therefore, prolonged and increased reactive hyperemia may initiate the functional and morphological changes in the vascular wall, and bring about the bone remodeling and arrangement of fibers in gingival tissue.[10,47,48]

The transient increase of blood flow in the human gingiva was reported by Baab et al.[11] They only described the differences in magnitude of the reactive hyperemia due to the biting force between gingival tissue types, and did not state the relationship between the reactive hyperemia and the degree and duration of force. Another important finding in our study is that reactive hyperemia was observed in the attached gingiva after releasing force, and its magnitude ($C/A \times 100$) was negatively correlated ($r = -0.639$) to the decreased blood flow ($B/A \times 100$). Furthermore, the duration of reactive hyperemia had a positive correlation ($r = 0.757$) to the duration of application of force, and a mild correlation ($r = 0.385$) to the degree of force and a mild correlation ($r = -0.340$) to the decreased blood flow. There have been arguments about the optimal force for orthodontic tooth movements concerning the degree and duration of force (light continuous, light intermittent, heavy interrupted forces),[10,49] however, there is little evidence explaining why the degree and duration of orthodontic force is important for optimal tooth movement. The findings of our study concerning the reactive hyperemia possibly explain the significance of the degree and duration of orthodontic force for tooth movement.

4. Method of measurement

There are several methods of measuring blood flow; among those, the plethysmographic recording has been introduced to the oral tissue,[3,4] however, it cannot be used for measuring gingival blood flow in humans because of its technical and mechanical complications. The electrolytic hydrogen clearance method is an alternate technique,[21] where an electrode is inserted into the tissue (which is invasive to the tissue and

may alter blood flow) and the velocity of diffusion of ionized hydrogens are measured (for short and interrupted periods). The thermal diffusion method requires placing a sensor directly into the tissue.[14] These methods are not suitable for continuous and non-invasive measurement of blood flow in human gingiva. Laser Doppler flowmetry has been verified to be reliable by other methods, such as plethysmography,[15] microspheres estimation,[21] and other methods.[17,50] The measurements made by the Laser Doppler flowmetry technique are highly correlated with the other measurements. To eliminate variability and increase reproducibility, the following points were considered. First, the fiberscopic probe was placed so as to avoid areas under large vessels because the number of red cells per cubic millimeter varies with the type of tissue, and the blood flow is calculated by multiplying the volume of red cells by their velocity in the Laser flowmetry. If there could be a significant difference in the number of red blood cells between two tissues and within the tissue, the blood flow should not be compared directly. In the attached gingiva, small vessels and pre- and post-capillaries are widely distributed.[27,28] Therefore, in this study the blood flow was recorded in the full-scale deflection, and its change in the gingival tissue was represented relative to its value during rest. Second, it is important to place and hold the fibroscopic probe properly. During blood flow measurements, the tip of the probe should not be in contact with the gingival tissue. Holloway et al.[18] and Gush et al.[20] reported that the Doppler shift increased with probe separation distance, however, probe separation of less than 2.0 mm did not significantly affect the blood flow parameters. In our study, blood flow in gingival tissue decreased rapidly and drastically due to the localized light pressure with probe, therefore, the tip of the probe was positioned 0.5 mm from the gingival mucosa. Accordingly, blood flow changes in the attached gingiva could be measured non-invasively. Furthermore, all measurements were carried out in a quiet room and at 20°C to 25°C room temperature after monitoring for 10 minutes to prevent undesired blood flow changes.[19,32]

In this way, the variability for each measurement and for each subject was reduced and the reproducibility was improved. As a result, there were no significant differences between the two recordings at the same position of probe. This means that there was high reliability and low variability on repeated measurements. The blood flow measurements during the resting period varied among different subjects even though all subjects were free from clinical signs of gingival inflammation, they may have different root length of the incisors, alveolar height, and/or thickness of the periodontal ligament. The displacement of teeth in the periodontal ligament is determined by these factors. The stress in the gingival tissue due to the same degree of force is not necessarily the same among subjects because the stress is possibly determined by the degree of displacement of teeth.

Conclusion

Gingival blood flow during the resting period varied among the subjects, however, by presenting the blood flow changes as the percentage over the resting level, it was possible to eliminate the variability of measuring blood flow among subjects. Gingival blood flow in humans decreased corresponding to the degree of force. The decreased blood flow gradually recovered to the resting level, and its recovery was dependent on the degree of force. Reactive hyperemia was observed after releasing applied force, and its duration was highly correlated to the duration of force application. Since blood flow measurement by Laser Doppler flowmetry is restricted in a small area, additional research is required to better understand the relationship between blood flow changes and tooth mobility. Laser Doppler flowmetry is useful for the clinical estimation of blood flow changes in human gingiva due to the application of orthodontic force.

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Commentary: Gingival blood flow

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Laser Doppler flowmetry can provide an index of relative blood flow changes from a variety of dentally relevant structures (e.g., gingiva, dental pulp, alveolar bone). Its non-invasive, continuous operation makes it well-suited for human clinical investigations. Consequently, this method's popularity will likely increase within the dental research community. Yamaguchi and his colleagues have shown an excellent example of how this technique can provide meaningful insight into the effects of orthodontic forces on gingival circulation.

This work suggests many interesting questions concerning the interface between orthodontics and periodontics. Are there blood flow changes in areas of minimal attached gingiva that might predict an episode of gingival recession in patients undergoing orthodontic expansion? Does space closure or the rotation of teeth chronically lower the blood supply to adjacent gingival tissue? Is there a certain level of orthodontic force beyond which ischemia may occur? Yamaguchi and colleagues have reported that heavy orthodontic forces caused reductions in gingival blood flow that did not recover to baseline levels within 10 minutes; it is unknown how long this effect persists. What are the gingival health implications of prolonged periods of reduced blood flow? By providing an index of

gingival blood flow that can be related to orthodontic forces, Laser Doppler flowmetry makes these and similar questions amenable to clinical investigation. A particularly interesting finding presented by these investigators is that the reduction in blood flow caused by an orthodontic force is more strongly related to the degree of subsequent reactive hyperemia ($r = 0.64$) than is the magnitude of force per se ($r = 0.32$). This emphasizes the point that while we can relate the magnitude of our orthodontic forces to a given outcome (e.g., amount of tooth movement), the physical measure of applied force is only an estimate for its physiological effects. Yamaguchi and colleagues similarly make this point when they state that "...the stress in the gingival tissue due to the same degree of force is not necessarily the same among subjects..." (p. 201). Methodologies that provide a physiological (rather than physical) index of the magnitude of applied force may improve our ability to compare orthodontic forces between patients as well as helping to determine the amount of force needed to produce an "optimal" physiological response in an individual patient.

While Laser Doppler flowmetry has a number of advantages that make it attractive for clinical research applications, it also has significant limitations that mitigate against its routine use in clinical practice. For example, baseline gingival blood flow estimates obtained using Laser Doppler flowmetry differ widely between subjects as has been demonstrated in the present study ($p < 0.01$). Because Laser Doppler flowmetry does not provide a measure of actual blood flow to compare individual subjects or sites, data are typically transformed to a percent change from baseline score which permits comparisons between subjects. Another limitation is that this methodology is quite sensitive to movement artifacts; stability of the measurement probe relative to the tissue is crucial. Positioning stents used by Baab et al.[1] provide stability as well as localization of the blood flow measurements to the same microvascular bed. This is important since resting blood flow measurements vary widely with small changes in the location of the measurement probe. Indeed, this spatial variability in blood flow suggests another important area for future research. With technological advances in Laser Doppler flowmetry, it may eventually be possible to use multiple probes to assess different sites simultaneously, or a laser-scanning technique that maps blood flow changes from a larger area of gingival tissue. These mapping techniques would provide a more complete picture of the way in which orthodontic forces are distributed through the gingival tissues.

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