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Relationship between the quantity of gingival crevicular fluid and clinical periodontal status

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Abstract: In order to analyze the possible relationship between the quantity of gingival crevicular fluid (GCF) and clinical periodontal status, the severity of gingival inflammation (gingival index (GI) scores) and probing depth (PD) were recorded and GCF samples were obtained from 1111 sites. These sites were further analyzed on the basis of distinct tooth groups to evaluate the significance of particular anatomical sampling locations. Statistical analysis of cumulative data showed significant increases in GCF volume with greater GI scores and PD. Correlations between GCF volume and both of the clinical measures were also strongly positive and significant for all sites. However, significant differences in GCF volume were observed between the anterior and posterior sampling sites. Increases in volume with increasing GI and PD were more marked for incisor and canine teeth. Similarly, the relationship between the quantity of GCF and clinical periodontal status was more clear and absolute in the anterior region than in the premolar and molar areas. These findings suggest that the quantity of GCF is not constant throughout the entire dentition, and that the relationship between GCF measurements and clinical periodontal status is site-based. This unique feature of GCF seems to be an essential factor in the design of GCF-related studies. (J. Oral Sci. 42, 231-238, 2000)

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Introduction

Gingival crevicular fluid (GCF) measurements (volume and flow rate) are among the most extensively studied potential indicators of inflammatory changes in periodontal diseases (1,2). Although most of these studies report enhanced GCF volume (3-8) or GCF flow (1,9-12) with periodontal disease and suggest that such measurements are better and more reliable indicators of periodontal alterations than most clinical parameters (1,10,12-14), the mechanisms underlying the formation, composition, passage and flow of GCF are not clearly understood (15). The relationships of GCF volume and flow rate with clinical and histological characteristics of inflammation are still controversial (2). Some studies show a relationship between GCF measurements and both clinical signs of gingival inflammation (11,12,16-18) and histological inflammatory changes (16-18). Others report the lack of such clear correlations between GCF measurements and periodontal status (10,13,14,19,20). Relationships between GCF measurements and clinical parameters also seem to vary among periodontal disease categories (1,8).

GCF volume and GCF composition have been shown to differ significantly among sample sites (3,10,13,20). Greater GCF volumes have been shown at posterior sites than at anterior sites (13), at mandibular sites than at maxillary sites (20) and at interproximal posterior sites than at anterior labial sites (3). In a study in which GCF volume and the lysosomal enzyme content of GCF were

Table 1 Mean GCF volume and statistical differences among subgroups based on GI and PD (Kruskal-Wallis test and Mann Whitney U-test with Bonferroni correction)
* Significant ($p < 0.001$)

Sampling area	Clinical measure	n	µl GCF Arithmetic Mean ± SEM	Kruskal-Wallis test X^2 p	Mann Whitney U-Test with Bonferroni correction U p
ALL SITEs (n=1111)	GI			446.919 0.0001*	0-1 29077.5 0.0001*
	0	270	0.07±0.004		0-2 7209.50 0.0001*
	1	387	0.16±0.008		0-3 1729.00 0.0001*
	2	301	0.30±0.012		1-2 30665.5 0.0001*
	3	153	0.40±0.018		1-3 9674.50 0.0001*
					2-3 16542.5 0.0001*
ALL SITEs (n=1111)	PD			459.594 0.0001*	
	Group 1 (<3mm)	395	0.08±0.004		1-2 29133.5 0.0001*
	Group 2 (3-5mm)	371	0.22±0.009		1-3 10433.0 0.0001*
	Group 3 (>5mm)	345	0.35±0.012		2-3 38478.5 0.0001*

simultaneously analyzed, variations in both GCF volume and enzymatic activity (greater for GCF volume) were reported among sampling sites (13). It has been suggested that GCF volume depends mainly on the dimensions of the crevicular space, variations in anatomy, susceptibility of the sites to inflammation, gravitational effect, the method of collection and sampling time (8,10,14,15,20).Therefore, it has been suggested that volumetric fluctuations among sites be considered in the methodological design and analysis of GCF studies (20).

The aim of the present study was to analyze the relationship between clinical periodontal status and GCF volume. The effect of the location of the sampling area was also considered.

Materials and Methods

A total of 1111 GCF sampling sites were included in the study. For determination of clinical periodontal status of the sampling area, gingival index (GI) (21) scores and probing depth (PD) were measured at each site. GCF samples were obtained by the use of standardized paper strips according to the method described by Rudin et al. (17). In brief, the sampling area was isolated with cotton rolls, and plaque was removed. After gentle air-drying, paper strips with a safeguard notch at the entrance were inserted 1 mm into the sulcus or pocket and left there for 30 seconds. To avoid any volumetric effect, GCF samples were obtained before clinical recordings. The strips containing GCF were immediately transported to a previously calibrated Periotron 8000 for volumetric determination. The quantity of GCF was measured in microliters.

In order to statistically evaluate the relationship between gingival status (based on the GI score of the sampling area) and GCF volume, the sampling sites were divided into 4 subgroups as follows:

Group 1= GI-0: No inflammation

Group 2= GI-1: Mild to moderate inflammatory gingival changes, not extending around the tooth

Group 3=GI-2: Mild to moderately gingivitis extending all around the tooth

Group 4= GI-3: Severe gingivitis characterized by marked redness, swelling, tendency to bleed and ulceration

For statistical analysis of the relationship between PD and GCF volume sampling, sites were divided into 3 subgroups as follows:

Group 1= PD <3 mm

Group 2= PD 3-5 mm

Group 3= PD >5 mm

To analyze the possible effect of the location of the GCF sampling area on GCF volume and the relationship beween clinical periodontal status and GCF volume on different sampling sites, the sampling sites (n = 1111) were further classified on the basis of distinct teeth groups, as incisor (n = 614), canine (n = 189), premolar (n = 213) and molar (n = 95), and these main groups were divided into subgroups on basis of the clinical periodontal status as described above.

Since data based on GI and PD were not normally

Table 2 Mean GCF volume and statistical differences among subgroups based on GI scores (ANOVA and Tukey's HSD test)
* Significant ($p < 0.05$).

Sampling area	GI	n	µl GCF Arithmetic Mean ± SEM	ANOVA F p	Post-hoc test Tukey's HSD p
INCISOR (n=614)				102.149 0.0001*	0-1 0.0001*
	0	184	0.06±0.004		0-2 0.0001*
	1	210	0.15±0.009		0-3 0.0001*
	2	138	0.27±0.017		1-2 0.0001*
	3	82	0.34±0.021		1-3 0.0001*
					2-3 0.0020*
CANINE (n=189)				37.210 0.0001*	0-1 0.3230
	0	55	0.08±0.012		0-2 0.0001*
	1	66	0.13±0.017		0-3 0.0001*
	2	46	0.25±0.027		1-2 0.0001*
	3	22	0.45±0.049		1-3 0.0001*
					0-2 0.013*
PREMOLAR (n=213)				0.862 0.462	–
	0	24	0.09±0.019		
	1	80	0.18±0.019		
	2	73	0.34±0.028		
	3	36	0.46±0.039		
MOLAR (n=95)				7.269 0.0001*	0-3 0.002*
	0	7	0.09±0.028		1-2 0.039*
	1	31	0.24±0.033		1-3 0.005*
	2	44	0.39±0.036		2-3 0.401
	3	13	0.50±0.093		

distributed (results of Levene's test), the nonparametric Kruskal-Wallis test was used to analyze the differences in GCF volume among subgroups for all sites. When there was a difference, groups were bilaterally compared by use of the Mann Whitney-U test with Bonferroni correction. Differences among subgroups based on the GCF sampling area were evaluated by analysis of variance. When a difference was observed among multiple groups, Tukey's HSD test was used for bilateral comparisons. The possible correlations between the clinical measures and the GCF volume for all of the sampling sites and also in subgroups classified according to the GCF sampling area were statistically analyzed by simple correlation analysis (Pearson correlation coefficient) with Bonferroni correction (22,23).

Results

Mean GCF volumes for all sites and statistical data regarding differences among subgroups based on GI and PD are shown in Table 1. Mean GCF volumes for distinct locations of GCF sampling and statistical data regarding subgroups based on GI are shown in Table 2. Table 3 shows same data based on PD. For all sites, GCF volume was significantly increased with increasing GI scores and increasing PD ($p < 0.05$). Where the location of the sampling area was considered, anterior teeth (incisors and canines) presented the same pattern of volumetric increase with greater GI and PD ($p = 0.0001$), except for the difference between GI-0 and GI-1 in the canine group ($p > 0.05$). However, the data for the premolar and molar tooth areas were statistically different from the data for all sites and anterior teeth. For the premolar areas, an increase

Table 3 Mean GCF volume and statistical differences among subgroups based on PD (ANOVA and Tukey's HSD Test)
* Significant ($p < 0.05$).

Sampling area	PD	n	µl GCF Arithmetic Mean ± SEM	ANOVA F p	Post-hoc test Tukey's HSD p
INCISOR (n=614)	Group 1(<3mm)	247	0.06±0.004	159.103 0.0001*	1-2 0.0001*
	Group 2(3-5mm)	199	0.19±0.011		1-3 0.0001*
	Group 3(>5mm)	168	0.32±0.016		2-3 0.0001*
CANINE (n=189)	Group 1(<3mm)	90	0.08±0.010	42.702 0.0001*	1-2 0.0001*
	Group 2(3-5mm)	51	0.20±0.024		1-3 0.0001*
	Group 3(>5mm)	48	0.34±0.033		2-3 0.0001*
PREMOLAR (n=213)	Group 1(<3mm)	46	0.10±0.020	0.767 0.466	–
	Group 2(3-5mm)	82	0.24±0.023		
	Group 3(>5mm)	85	0.39±0.025		
MOLAR (n=95)	Group 1(<3mm)	12	0.17±0.049	3.894 0.024*	1-2 0.198
	Group 2(3-5mm)	39	0.31±0.043		1-3 0.021*
	Group 3(>5mm)	44	0.39±0.036		2-3 0.328

in GCF volume was observed with greater GI and PD, but volumetric fluctuations were all not significant ($p > 0.05$). For molar areas, the increase in GCF volume was not significant between GI-0 and GI-1 ($p > 0.05$) nor between GI-2 and GI-3 ($p > 0.05$). On the basis of PD, the only significant volumetric difference (increase) was seen between Group 1 and Group 3 ($p < 0.05$).

Great fluctuations in the quantity of GCF were observed among sampling sites. Table 4 shows the variances in the range of GCF volume among distinct sampling locations. Under similar periodontal conditions, when compared with anterior teeth (incisors and canines), greater GCF volumes in the posterior locations, being the highest in molar tooth areas, were observed, but owing to the unequal distribution of groups, reliable statistical analysis could not be performed.

Correlations between GCF volume and clinical parameters for all sites and sampling locations and r and p values are shown in Table 5. For all sites there was a strongly positive and significant correlation between GCF volume and both of the clinical measures ($p < 0.05$). The GCF volumes showed strongly positive and significant correlations with both GI scores and PD in anterior teeth (incisors and canines), which was the same as data obtained from all sites together ($p < 0.05$). In the premolar region, the GCF volume showed a strongly positive and significant correlation with GI, but a weakly positive and significant correlation with PD. For the premolar tooth areas, the correlations between GCF volume and clinical measures were both weakly positive and significant ($p < 0.05$).

Discussion

When the differences in GCF volume among 1111 sampling sites were statistically analyzed in a cumulative manner, it was observed that quantity of GCF consistently increased with higher GI scores. Similarly, it was shown that more GCF could be collected from deep periodontal pockets. Simple correlation analysis of cumulative data also confirmed this, since strongly positive and significant correlations were found between the amount of GCF and both of the clinical measures. In most previous studies, enhanced GCF volume in periodontal disease has been reported, and it has been suggested that GCF measurements are related to clinical periodontal status (11,12,16-18).Therefore, our cumulative results, based on mean GI scores and mean PD, support the findings of such previous studies, suggesting that quantity of GCF is related to clinical periodontal status. Since the correlations for GCF volume were similar for both clinical parameters, it can also be suggested that the quantity of GCF is related both to the severity of gingival inflammation and also to the degree of periodontal destruction.

Table 4 Descriptive statistical data regarding volumetric fluctuations of GCF (μl) among distinct sampling locations with matching clinical periodontal status

Sampling site	PD	GI	Minimum	Maximum	Arithmetic Mean	S.E.M
INCISOR	PD <3mm	GI-0	0	.09	.0539	.003
		GI-1	0	.42	.0897	.010
		GI-2	–	–	–	
		GI-3	–	–	–	
	PD 3-5mm	GI-0	–	–	–	–
		GI-1	.02	.70	.1385	.012
		GI-2	.01	.73	.2441	.020
		GI-3	.10	.60	.2741	.027
	PD >5mm	GI-0	–	–	–	–
		GI-1	.04	.70	.2579	.026
		GI-2	.02	.94	.3103	.028
		GI-3	.02	.85	.3698	.027
CANINE	PD <3mm	GI-0	0	.44	.0764	.012
		GI-1	0.01	.47	.0899	.017
		GI-2	–	–	–	–
		GI-3	–	–	–	–
	PD 3-5mm	GI-0	–	–	–	–
		GI-1	.01	.70	.1700	.038
		GI-2	0	.70	.2005	.028
		GI-3	.22	.70	.4100	.102
	PD >5mm	GI-0	–	–	–	–
		GI-1	.02	.39	.1678	.041
		GI-2	.06	.74	.3305	.048
		GI-3	.14	.94	.4550	.057
PREMOLAR	PD <3mm	GI-0	.02	.33	.0782	.022
		GI-1	.01	.47	.0837	.019
		GI-2	–	–	–	–
		GI-3	–	–	–	–
	PD 3-5mm	GI-0	–	–	–	–
		GI-1	.01	.79	.1597	.030
		GI-2	.01	.72	.2597	.034
		GI-3	.18	.80	.4462	.054
	PD >5mm	GI-0	–	–	–	–
		GI-1	.08	.70	.3168	.034
		GI-2	.04	.94	.4005	.040
		GI-3	.09	.88	.4691	.054
MOLAR	PD <3mm	GI-0	.02	.13	.0580	.020
		GI-1	.15	.24	.1800	.030
		GI-2	–	–	–	–
		GI-3	–	–	–	–
	PD 3-5mm	GI-0	–	–	–	–
		GI-1	0	.73	.1895	.053
		GI-2	.09	.82	.3910	.058
		GI-3	.07	.96	.3950	.210
	PD >5mm	GI-0	–	–	–	–
		GI-1	.07	.67	.3108	.045
		GI-2	.12	.78	.3940	.050
		GI-3	.22	.93	.5456	.102

Table 5 Correlations between GCF volume and clinical measures based on all sites and distinct sampling locations (Simple correlation analysis with Bonferroni correction)
* strongly positive and significant
** weakly positive and significant

Measures	r	p
All sites		
µl GCF-GI	0.559	0.0001*
µl GCF-PD	0.545	0.0001*
Incisor		
µl GCF-GI	0.575	0.0001*
µl GCF-PD	0.585	0.0001*
Canine		
µl GCF-GI	0.584	0.0001*
µl GCF-PD	0.561	0.0001*
Premolar		
µl GCF-GI	0.511	0.0001*
µl GCF-PD	0.486	0.0001**
Molar		
µl GCF-GI	0.438	0.0001**
µl GCF-PD	0.274	0.0070**

Despite an early study in which GCF collected from 2 reference maxillary sites was taken to to represent the fluid on the whole upper arch (12), in most recent studies variance in GCF volume among different sampling locations has been reported (10,11,13,20). In a study in which GCF was collected from the areas around the upper right first molar and lower right canine, a higher GCF volume and flow rate was shown in the molar area, independent of the clinical periodontal status, indicating that anatomically different tooth types lead to substantially different pooled GCF volumes. Fluctuations in GCF volume among sampling sites were reported to be more marked than fluctuations in GCF flow rates. The authors also suggested that the volumes of initial samples, representing accumulated GCF, were more related to the dimensions of the crevicular space than the degree of gingival inflammation or probing depth (10). In another study, GCF volume and enzymatic composition were reported to be strikingly different among 8 proximal surfaces of premolars, first molars and second molars. More fluid could be obtained from the posterior regions in both periodontal health and disease states, and volumetric differences were related to the location of the sampling area rather than clinical periodontal status. Therefore, the authors suggested considering the variability in the amount and composition of GCF among sampling locations when the analysis of GCF parameters is attempted (13).

When the quantity and composition of GCF from 6 maxillary and mandibular sites with signs of gingivitis were analyzed, greater GCF volumes were found in mandibular sites than at maxillary sites. Differences in the quantities of GCF constituents among sites were less than differences in GCF volume, and these volumetric differences were not related to the variability in sulcular anatomy (20). Under conditions of periodontal health, the GCF volume collected from anterior labial sites was reported to be significantly lower than that from interproximal posterior sites (3). Lamster et al. (24) reported a general fluctuation in mean interproximal and buccal GCF volumes within sites afffected by gingivitis and periodontitis, supporting the view that the type of sampling site affects GCF volume. They also suggested that the amount of fluid collected by the paper strip is determined by the amount of fluid available in the crevice and not the capacity of the strip to retain GCF.

Due to the great volumetric fluctuations among sites observed in the present study, our findings are in agreement

with previous studies, which have found variation in the amount of GCF among various anatomical sites (10,13,20,24). Although in all anatomical locations greater amounts of GCF could be collected with increasing gingival inflammation and PD, this volumetric increase was more marked in the anterior region. Absolute and clear correlations between the quantity of GCF and clinical parameters were also observed in these tooth groups. The significant increases in GCF volume and the clear relationship between GCF volume and clinical periodontal status observed in cumulative analysis (n = 1111) were not achieved in every sampling location. Since anterior and posterior teeth responded differently, our findings may confirm previous data suggesting that GCF volume is not consistent throughout the entire dentition, and that the location of the GCF sampling site has a significant effect on GCF measurements (3,10,13,20).

The volumetric differences in GCF among sites are attributed to several factors, including variations in anatomy, the size of the crevice, a gravitational effect and the susceptability of the sites to inflammation (10). Furthermore, it has been suggested that GI and PD could not explain the volumetric differences with sampling location, and volumetric differences could reflect differences in inflammation not shown by GI (13). The greater amount of GCF found in mandibular sites has been considered to be related to the more ready downward flow of fluid in the maxilla than upward from the mandible (20). The relationship between GCF volume and clinical periodontal status has also been thought to be related to the characteristic features of periodontal disease and to show individual and site differences (8).Different methods of GCF collection and sampling times have also been proposed as explaining the differences found in the relationships between GCF measurements and clinical parameters (10,15). All of these factors seem to have some contribution to the volumetric fluctuations among sites. Further studies considering the formation, passage and flow of GCF may help in a better understanding of the nature and volumetric dynamics of GCF.

When taken together, these findings may support the concept that the relationship between GCF measurements and clinical periodontal status is site-dependent. Therefore, the location of the GCF sampling area should be considered in the design and analysis of GCF-related studies.

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