Clinical adhesiveness of the tooth surface

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The clinical adhesiveness of tooth structure was determined for 43 individuals using intraoral contact angle measurements. There were no statistically significant differences in the critical surface tensions of wetting between groups of males and females nor between the three age groups tested. There was a statistically significant difference between individuals. The critical surface tensions for all the tooth surfaces measured were in the bioadhesive range of 32 – 50 dynes/cm. The formation of an organic film, pellicle, on the surfaces of teeth brings groups of different ages and sex to a common state of bioadhesiveness, allowing for the subsequent bacterial colonization and plaque formation as a clinical consequence.

Key-words: Pellicle; critical surface tension, age and sex

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Clinicians and scientists alike agree that the two most prevalent dental dieases, caries and periodontal disease, are initially related to the surfaces of teeth. It is further generally accepted that the surfaces of teeth are covered by an organic component, the acquired pellicle (10). Subsequently, adsorbtion of microorganisms develops into the dental integument recognized as dental plaque (4). The work of adhesion of this dental plaque is influenced by the surface chemical properties of the teeth (6, 7) and the presence of an adsorbed organic film has been found to modify the adhesiveness of intraorally positioned experimental surfaces (3). These observations suggest that the adsorbed organic film of aquired pellicle plays a dominant role in most successive clinical adhesive events on the tooth surface *in vivo*. It does in fact create the clinical solid liquid interfaces in the oral cavity. The general and specific nature of this pellicle has been investigated and discussed by many scientists working in several different disciplines (1, 3, 9, 10, 15). Much of the previous work on the adhesiveness of adsorbed pellicles has been conducted *in vitro* with only limited studies performed *in vivo* (2, 6).

Recently a new clinical method for the study of the *in vivo* adhesiveness of teeth has been presented by Glantz, Jendresen & Baier (8). This method employs the use of *in vivo* contact angle measurements to calculate the critical surface tension of wetting, which Zisman (16) demonstrated to have a direct relationship with the practical adhesiveness.

Using this method it was considered worth while to study the *in vivo* adhesiveness of normal tooth surfaces of healthy male and female subjects from various age groups.

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MATERIALS AND METHODS

Forthy-three adults were selected as test persons to be studied from a population of University students and faculty. The sample was composed of 18 females and 25 males. The subjects ranged in age from 19 years to 64 years. The subjects were divided into three groups by age. Group I comprised ages 19–25 years (7 females/2 males), group II included ages 26–39 (6 females/14 males) and group III consisted of subjects 40–64 years of age (5 females/9 males). Table 1 shows the distribution of evaluations by test subjects' age and sex. All of the test persons considered themeselves to be in good general health and were found to be free of any profound dental disease upon clinical dental examination.

Using the materials and methods described in detail by Glantz et al (8), multiple *in vivo*-contact angle measurements were conducted on the labial portions of the front teeth of randomly selected test persons. This provided information on some subjects over a period of several days and on others over a period of several weeks. Four (4) complete evaluations were conducted on some test persons.

From the contact angle data obtained, the critical surface tensions according to Zisman (16) were calculated individually for the polar as well as the non-polar liquids. Studies on some possible sources of error in the method are previously reported (8).

RESULTS

The calculated critical surface tension (γ_c) means and their standard deviations were derived from the polar (γ_c^p) and non-polar (γ_c^d) test liquids. The results obtained between the sexes as groups are given in Table 2. These values represent the means of the critical surface tensions calculated individually from the relationship between the surface tensions (γ_{LV}) of the various test liquids and the cosines of the recorded contact angles (Θ). In a similar fashion, Table 3 shows the means and standard deviations of the calculated critical surface tensions by age group, using both the polar and non-polar liquids.

The results given in Tables 2 and 3 indicate that the anterior teeth of the persons tested had low energy surfaces with similar wetting properties between males and females, as well as between the different age groups tested. In order to study in greater detail the possible significance of differences observed between the data obtained from the female subjects and the male subjects, an analysis of variance was performed. Analyses of variance were also performed on the data obtained from the three different age groups established as well as from the individual test persons. The program used was Statistical Package for the Social Sciences, Sperry Univac 1100 exec. 8, Version H, September 1978.

The results of these analysis showed that there were no statistically significant differences between any of the critical surface tensions calculated from contact angle recordings obtained from male or female test persons; and likewise there were no such differences between the calculated critical surface tensions of the three age groups. For the individual test persons, however, statistically significant differences ($p < 0.0001$) were found between the calculated critical surface tensions for non-polar test liquids. There was no measurable difference between separate teeth in the same mouth, between different times of day, or between days in the month (except for two women). Further investigation revealed that pronounced cyclic changes in the critical surface tension of wetting on the tooth surfaces of these two women coincided exactly with their menstrual cycles.

Table 1. *Distribution of critical surface tension measurements by test persons' age and sex*

Group I 19 – 29 years		Group II 26 – 39 years		Group III 40 – 64 years	
Age	n	Age	n	Age	n
19	1	26	6	40	1
20	4	28	13	41	4
21	3	30	1	42	3
23	2	31	3	44	3
25	5	33	4	48	2
		34	1	49	3
		35	2	54	5
		37	3	59	1
		38	2	63	1
		39	2	64	1
Total	15		37		24
Females/ males	10/5		9/28		10/14

Table 2. *The calculated critical surface tensions (dynes/cm) between the sexes as groups, derived from polar (γ_c^p) and non-polar (γ_c^d) test liquids*

Critical surface tension	γ_c^p			γ_c^d		
Evaluation	Female	Male	Total	Female	Male	Total
Mean	37.6	50.1	45.3	33.3	32.6	32.9
Standard Deviation	103.2	38.6	70.2	5.3	4.2	4.7
n	29	47	76	29	47	76

Table 3. *The calculated critical surface tensions (dynes/cm) by age groups, derived from the polar (γ_c^p) and non-polar (γ_c^d) test liquids*

Age group	I		II		III	
Critical surface tension	γ_c^p	γ_c^d	γ_c^p	γ_c^d	γ_c^p	γ_c^d
Mean	44,6	31.6	45.8	33.7	45.2	32.4
Standard Deviation	5.4	3.5	21.4	5.0	123.9	4.6
n	15	15	37	37	24	24

DISCUSSION

The presence, composition, and role of the acquired pellicle on the surface of teeth has been studied by many investigators (6, 7, 9, 10, 14, 15). Some of these studies indicated that tooth structure was normally covered by low energy material, which may originate from the tooth itself, while others indicated that the acquired pellicle forms on solid surfaces in the oral cavity by adsorption of salivary glycoproteins. The data obtained in this study does indeed agree with the previous findings.

The measurement of contact angles formed on clean normal untreated enamel surfaces *in vivo* with selected pure test liquids of known surface tensions indicated the presence of a low energy surface with a similar degree of wettability between males and females. Further, this same degree of wettability existed between a wide range of ages. The mean critical surface tensions of wetting on the tooth surface between males and females for the non-polar liquids was 32.6 dynes/cm for males and 33.3 dynes/cm for the females. This same relationship existed between the three age groups, i.e., a difference of less than 2 dynes/cm.

When the mean critical surface tensions for the polar liquids were calculated for the sexes by groups, the value was 45.3 dynes/cm with a standard deviation of 70.2 dynes/cm. Similar higher values were seen in the age group determinations using the polar test liquids. The high standard deviation in these instances using the polar liquids may be attributed to the fact that only recordings from two polar test liquids (glycerol and thiodiglycol) were used in the calculations of the γ_c^p-values (8). A contributing factor could also be changes in the pellicle-water content through evaporation during the evaluations. If this occured it could particulary affect the degree of polar force interaction across the pellicle/polar test liquid interface.

There appears to be a high degree of stability in the film formation and maintenance. Repeated measurements over periods of hours, days and weeks on the same subjects showed a remarkable repetition in the critical surface tensions (γ_c) of their measured surfaces.

There was, however, a pronounced variation of the surface free energy on the teeth in two female test persons evaluated over a period of several weeks. Noteworthy is the observation that the cyclic variation in the adhesiveness of the biofilm of these two women was concurrent with their menstrual cycles. This is, albeit, a limited and unplanned observation from this study; however, it may suggest that there is some hormonal influences on the biofilm. It further intimates, as has been suggested by some investigators, that the film has a frequent turnover rate.

The one significant difference ($p < 0.0001$), seen in this study was the difference of the critical surface tensions between individuals derived from the non-polar liquids (γ_c^d). This difference may be attributed to the dominance of certain glycoproteins in some individuals or as suggested by Rölla, Bonesvoll & Opermann (12), that the salivary blood group substance contributes to specificity. Another consideration is the individual film surface potential. According to the laws of colloid chemistry, slightly different surface potentials will effect the adhesiveness of particles (for reviews see (5) and (13)). This concept is conceivable considering the work of Olsson & Glantz (11), with the effect of pH and counter ions on the Zeta potential of plaque forming oral bacteria.

The results from this study show that the adhesiveness of pellicle covered normal tooth enamel in the average oral cavity of moderate plaque forming and cariogenic potentials is essentially the same over a wide human population. The differences are very small and hardly significant from person to person. The ad-

sorption of a similar film forming substance brings their surface properties to a common state. That common state falls into a surface energy range identified from prior studies as bioadhesive, in that it is a precursor for colonization and growth of secondary biological layers, bacteria and plaque. One could predict that inherent non-plaque forming persons may have an acquired pellicle or biofilm on the surfaces of their teeth that has a critical surface tension of wetting lower than the range for the average person. The films formed on these non-plaque forming individuals may in fact be bioabhesive and not subject to colonization by oral microorganisms and the subsequent plaque population. Baier (2) described the bioabhesive range to be a critical surface tension in the order of 25–30 dynes/cm.

The original research question to be answered in this study was answered in the affirmative; the nature of surfaces in the diversity of healthy human cases was very much the same, and the clinical consequences are therefore also expected to be very much the same.

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REFERENCES

1. Armstrong, W.G. & Hayward, A.F. Acquired organic integuments of human enamel. A comparison of analytical studies with optical, phase-contrast and electron microscope examinations. Caries Res. 1968, 2, 294 – 305
2. Baier, R.E. Occurrence, nature and extent of cohesive and adhesive forces in dental integuments. In: Lasslo, A. & Quintana, R.P., eds. Surface Chemistry and Dental Integuments. C.C. Thomas, Publisher, Springfield, Ill. 1973, pp 337 – 391
3. Baier, R.E. & Glantz, P.-O. Characterization of oral in vivo films formed on different types of solid surfaces. Acta Odontol. Scand. 1978, 36, 289 – 309
4. Dawes, C., Jenkins, G.N. & Tonge, C.H. The nomenclature of the integuments of the enemal surface of teeth. Br. Dent. J. 1963, 115, 65 – 68
5. Friberg, S. Colloid phenomena encountered in the bacterial adhesion to the tooth surface. Swed. Dent. J. 1977, 1, 207 – 214
6. Glantz, P.-O. On wettability and adhesiveness. Odontol. Revy 1969, 20, Suppl. 17, 1 – 132
7. Glantz, P.-O. The adhesiveness of teeth. J. Coll. Interf. Sci. 1971, 37, 281 – 290
8. Glantz, P.-O., Jendresen, M.D. & Baier, R.E. A clinical method for the study of in vivo adhesiveness of teeth. Acta Odontol. Scand. 1980
9. Mayhall, C.W. Concerning the composition and source of the acquired enamel pellicle of human teeth. Arch. Oral Biol. 1970, 15, 1327 – 1341
10. Meckel, A.H. The formation and properties of organic films on teeth. Arch. Oral Biol. 1965, 10, 585 – 597
11. Olsson, J. & Glantz, P.-O. Effect of pH and counter ions on the Zetapotential of oral streptococci. Arch. Oral Biol. 1977, 22, 461 – 466
12. Rölla, G., Bonesvoll, P. & Opermann, R. Interactions between oral streptococci and salivary proteins. Proceedings «Saliva and Dental Caries». Eds. Kleinberg, I., Ellison, S.A. & Mandel, I.D. Sp. Supp. Microbiology Abstracts 1979, 227 – 241
13. Shaw, D.J. Introduction to colloid and surface chemistry. Butterworth, London, 1970, pp 1 – 236
14. Sönju, T. & Glantz, P.-O. Chemical composition of salivary integuments formed in vivo on solids with some established surface characteristics. Arch. Oral Biol. 1975, 20, 687 – 691
15. Sönju. T. & Rölla, G. Chemical analysis of the acquired pellicle formed in two hours on cleaned human teeth in vivo. Rate of formation and amino acid analysis. Caries Res. 1973, 7, 30 – 38
16. Zisman, W.A. Relation of the equilibrium contact angle to liquid and solid constitution. In: Gould, R. ed. Contact angle, wettability and adhesion. Advances in Chemistry Series No. 43, American Chemical Society, Washington D.C., 1964, pp 1 – 51