1969

Effects of Aging on Human Teeth

Edward F. Kastelic
Loyola University Chicago

EFFECTS OF AGING ON HUMAN TEETH

BY

Edward F. Kastelic, B.S., D.D.S, M.P.H.

A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Master of Science

May
1969

ACKNOWLEDGEMENTS

I wish to express my appreciation and sincere thanks to:

Dr. Patrick Toto for acting as my advisor. Without his counsel and advice this project would not have been possible.

Dr. Gustav Rapp for his sincere interest and guidance in procedure and technology.

TABLE OF CONTENTS

CHAPTER I

REVIEW OF LITERATURE

"When a particular structure reaches the point in time where it begins to show an increasing inability to meet the demands of its environment or its normally expected function it may be assumed to have attained the period referred to as aging. This may be exhibited in the directions of curves in graphs depicting chemical or biological processes or in the more gross clinical manifestations of loss of substance or character of the structure or its parts."

A number of changes have been found to occur in human teeth coincident with chronological aging of the individual. Some of these changes are readily recognized on gross observation, such as abrasion, attrition, discoloration, and movement of teeth. Other dental age changes such as changes in supporting tissues and structural characteristics are more subtle, and recognized only after special tissue preparation and the use of more refined techniques.

Morphological criteria associated with aging of dental tissues have been explored to various extents with respect to all parts of the dental organ -- from the very hard surface of the externally exposed enamel to the delicate soft

tissue of the centrally located pulp. But the principal dental alterations of interest to early investigators concerned the structure of dentin, which serves as the bulk of the dental hard tissues.

W. D. Miller (1890) appears to be the first to attract scientific attention to the probable significance of certain histological changes in the dentin in response to age, wear and tear. Subsequently, Beust (1931, 1934), Bodecker and Lefkowitz (1937, 1946), Fish (1933), and others applied various tools to explore the nature of optical changes evidenced by the relative degree of opacity versus transparency of dentin. At the same time they showed a decrease in dentin permeability to dyes in connection with aging and in response to pathology. These findings suggested structural changes within the dentinal tubules, the minute "channels" which extend from the pulp, house the odontoblastic extensions, and permeate the whole dentin matrix.

Subsequently, Hill (1934) and Kronfeldt (1939) turned their attention to various microscopic changes that may be found in the seemingly well-protected pulp tissue of teeth of older individuals. Some of these changes begin, in fact, during early life. The dental papilla of the young tooth organ is densely packed with large round cells and non-fibrous ground substance (almost resembling young carti-

lage). In the adult pulp, typical fibroblasts become predominant. With aging, fibrosis, cellular atrophy, and other degenerative changes develop. Pathological calcification becomes extremely common; either as diffuse deposits; as fibrillar calcification along the increasing collagenous elements; or as full-fledged pulp stones or denticles composed of dentin, osseous or homogeneous hard tissue elements.

Although the morphology of the pulp has been extensively investigated, biochemical data are almost totally lacking. Hodge (1936), has found human pulps to contain 0.71 per cent phospholipid and 0.11 per cent cholesterol; total lipid content was 0.91 per cent (wet weight basis). Pincus (1950) has suggested that the pulp contains a mucoprotein, because of the presence of the hexosamines and its relatively low concentration. He also reported that dry pulp contained 5.7 per cent calcium and 3.5 per cent phosphorous.

Riedesel and Fischer (1954), and Fischer, Wait, Chalup, and Nash (1958), have shown that the nitrogen content of dental pulps averaged 11.7 per cent of dry weight and that there was a slight increase in the nitrogen level with age.

Yoon, Brudevold, Smith, and Gardner (1964), studied the fluoride, calcium, phosphate, ash and water content of human dentinal pulps. They found that while the fluoride,

organic and ash content increased with advancing age, the water content decreased. These and other age changes in the dental pulp are believed to warrant further exploration by more sophisticated tools.

To return to the external surface of the teeth -- it is generally recognized that the color of the enamel often tends to darken with age. But not only does the exposure to extraneous discoloring agents and oral hygiene habits vary greatly; so far there has been little effort to grade tooth color in relation to age change beyond the accuracy of the unaided human eye.

Scott, Haplan, and Wycoff (1949) have been able to make a very precise appraisal of age changes in the histomorphological pattern of the enamel surface by means of an indirect technique, namely by microscopic examination of celloidin replicas, shadowed with vaporized metal to obtain maximal optical contrast. With advancing age, they found a decrease in enamel surface detail of the labial-buccal and proximal tooth surfaces. The young enamel showed pronounced structure of perikymata (surface grooves and elevations reflecting the enamel appositional pattern) and numerous enamel rod ends; the next stage showed imprints of the rod ends to be fading away between perikymata; at older age, most rod ends were lost; and finally in the oldest specimen there was almost

complete loss of surface detail.

Gustafson (1950) appraised six dental age changes observed in routine longitudinal ground sections. He devised a method of age determination by combining semi-quantitative estimates of the extent of these changes, namely: (1) the increasing degree to which the enamel and subsequently the dentin are worn on the chewing surfaces of of teeth (attrition); (2) the increasing amount of internal dentin apposition which results in decrease in the size of the coronal pulp chamber (secondary dentin); (3) migration apically of the coronal-most position of the supporting structures of the teeth (peridontal attachment); (4) the increasing amount of cementum present as a result of continuous apposition (cementum apposition); (5) the increasing number of Howship's lacunae on the root surface (root resorption); and (6) the increased area of sclerosis in root dentin as evidenced by its glassy appearance in transmitted light (root transparency). By this combination of six dental landmarks, Gustafson was able to arrive at a good prediction of chronological age within a sample of Swedish individuals.

Zander and Hurzeler (1958) chose one of the above dental age changes for a more precise quantitative study. They

showed quite clearly that cementum thickness is directly related to age for single-rooted teeth with "healthy related tissues". Quantitative measurements were performed on two hundred thirty-three teeth from people of varying ages, who by clinical and X-ray examination showed no periodontal pockets or bone loss around the teeth chosen for study. Emphasis was placed on four areas of the root for cementum thickness measurements, obtained by projecting cross sections on an overhead screen. These areas were: (1) cementum thickness at the apex, (2) at the middle of the root, (3) at the crown end, near cemento-enamel junction, and (4) the total root, i.e., the average.

By plotting any of these four measurements versus age, a straight-line relationship between tooth age and cementum thickness was shown to hold. Apposition was greatest at the apex, somewhat less at the middle of the root, and least near the crown.

While most of the literature considers dental age changes from the microstructural point of view, it is to be noted that chemical age changes have also been examined.

Alterations in the distribution of inorganic substances in the enamel have been demonstrated by Brudevold (1957). The concentrations of P, CO_3, F, Pb, Sn and Cu in the enamel

of unerupted teeth and in teeth of successively older age groups were compared. When age changes in the concentrations of these substances occur, they appear to be most marked in the outer part of the enamel, which is exposed to the external environment, and least in the subsurface layer. Notably, fluoride is always in higher concentration in the surface enamel during the first decades of life. Lead is found in smaller concentrations but has a similar pattern of distribution whereas CO_3 is in lower concentration in the surface than in the subsurface layers and shows a decrease with age.

With regard to age changes in the organic part of enamel, as related to color of enamel (pigmentation), Bhussry (1957) demonstrated an increase in nitrogen content and a decrease in density of enamel with age.

To return to the largest fraction of the tooth -- the dentin, it consists of specialized cells and an intracellular substance. The dentin consists of thirty percent organic material and water, and seventy percent inorganic material. In 1951, Losee, et al., showed that the organic substance of dentin consists of collagenous fibrils and a ground substance containing mucopolysaccharides.

The effects of aging on the dentin are expressed by the deposition of new layers of dentin (secondary or separation dentin) and alteration of the original dentin (sclerotic dentin). The components of dentin do not change with age although an increase in the specific gravity of dentin with advancing age has been reported by Sicher (1961).

In the immature tooth, one finds large dentinal canals and vital odontoblastic processes with no sclerosis. As the tooth matures, the number of odontoblasts is progressively decreased and dentinal canals are eliminated by calcification. Here one finds canals of reduced caliber alternating with those eliminated and sclerosed. The strands of sclerosed tissue extending from the periphery to the pulp become wider and more numerous, and finally confluent, until in senescence the tooth may be composed almost completely of sclerosed dentin.

The sclerosing effect of the dentin in aging can be compared to similar changes in soft tissue. Most of the work has been performed on connective tissue of more accessible parts of the body, however, the collagen and mucopolysaccharide ground substance of the dentin are also components of connective tissues.

Sobel and his co-workers (1953, 1954, 1956, and 1958) studied the relations of collagen to hexosamine, and found that the gel to fiber ratio decreased with advancing age, in the skin of the rat, guinea pig, rabbit and man.

In two separate studies in 1962, Clausen determined age changes in the extracellular substance of the thoracic aorta, myocardium and skin in normal human fetuses aged eleven to nineteen weeks. He then compared the same tissues in autopsy material of eighty-seven persons aged four months to eighty-six years. In all of these organs, Clausen could demonstrate a significant and steady increase in the fibrous components in relation to ground substance. This has been corroborated by the work of Sinex in 1965. He stated, that in general, in advancing tissue age, collagen content increases and mucopolysaccharide content decreases.

With this preliminary survey of age changes in human teeth, it is suggested that changes in water content and organic material also occur with age.

The purpose of the present study is to demonstrate whether or not aging in a tooth is accompanied by water loss and a change in organic material content.

CHAPTER II

MATERIAL AND METHODS

This investigation was based upon an examination of extracted whole human permanent teeth randomly selected. The teeth were grouped according to the age of the patient from whom they were extracted. The teeth were selected to provide the widest variation in age possible, and were separated into two groups. Group I consisted of teeth from patients in the age group ten to fifteen years. Group II consisted of teeth from individuals beyond age fifty.

The teeth collected consisted of premolars and incisors and were relatively free of decay. Only teeth without restorations were accepted.

Immediately after extraction, the teeth were washed to remove all blood and debris, dried with a paper napkin, and placed in a sealed plastic bag which was then placed in the freezer compartment of a refrigerator.

The teeth which were collected and prepared in the foregoing manner were subjected to a study done in two parts.

Dehydration of Whole Teeth

In part A of this investigation, all teeth were weighed individually by means of a torsion balance and while remaining relatively frozen. Thus the original weight is a weight in the frozen state. The teeth were then placed in a wire mesh tooth rack which was placed in a Precision electric oven and maintained at a temperature of 105 degrees centigrade for ninety-six hours. The tooth rack was then removed from the oven and placed in a dessicator containing calcium chloride crystals. The teeth were allowed to cool to room temperature for approximately three hours. The teeth were then weighed. The difference in weight is assumed to be equivalent to the loss in water content. This procedure was repeated three times as water loss continued to occur and the investigator desired assurance of relatively complete dehydration.

Incineration of Whole Teeth

In part B of this investigation, the procedure necessitated a pooling of teeth. A porcelain crucible was weighed and then re-weighed containing six teeth. All the teeth in Groups I and II were thus pooled and incinerated in numbers of six. The crucibles were then placed in a gas-fired oven, and the temperature was brought slowly up to 2000 degrees

Farenheit and maintained at this temperature for three hours. The crucibles were then removed from the oven and placed in a dessicator after cooling to approximately 150 degrees Farenheit. The crucibles were then allowed to remain in the dessicator for three hours and then reweighed. The differences in weight are assumed to be due to removal of all remaining water and organic material.

CHAPTER III

FINDINGS

In part A of this investigation, whole teeth were dehydrated in a Precision electric over at 105° centigrade for ninety-six hours. Since the process of dehydration required time, a series of ninety-six hours was utilized to assure relatively complete dehydration.

In Group I, consisting of teeth from young individuals, the analysis of the data shows that the teeth continued to lose water with time. Significant differences exist between the weights after ninety-six and one hundred ninety-two hours of dehydration and one hundred ninety-two and two hundred eighty-eight hours was insignificant. (appendix page 27)

In Group II, consisting of teeth from older individuals, the investigator found insignificant differences between the sample weights after ninety-six and one hundred ninety-two and one hundred ninety-two and two hundred eighty-eight hours of dehydration. However, a significant difference exists between the additional losses of water between one hundred ninety-two and two hundred eighty-eight hours. (appendix Page 35)

Although the teeth selected for this investigation were selected at random and separated into two groups based on

age, examination of the data shows that Group I and Group II are significantly different in original weights based upon the student T-test. (appendix page 36). Therefore, it is not surprising that the differences between Groups I and II, at each weighing, i.e., ninety-six, one hundred ninety-two and two hundred eighty-eight hours are significantly different, and that the net water loss (V8) and total percent change (V9) between Groups I and II are also significant. (appendix pages 36-37). The resulting per cent total loss of water with dehydration was 12.1012% in the young group and 9.6895% in the older group. These results are highly significant as expressed in Table 1.

In part B of this investigation, the teeth in Groups I and II were pooled in series such that each crucible contained six or seven teeth. The crucibles were then heated in a gas oven at 2000° Farenheit for approximately three hours. At this time, the crucibles were examined and it was determined that incineration was incomplete and the teeth were heated for another three hours.

From the appendix (page 44), it can be seen that the initial sample weights were not significantly different and the total loss of the sample of organic material based on weight was also insignificant. However, the per cent loss

in Group I was 21.2991 and in Group II, 24.1859. These results are highly significant as expressed in Table II. The per cent difference between Group I and Group II is also highly significant.

TABLE I

DEHYDRATION AT 105° F. FOR 288 HOURS

	GROUP I (15) (YEARS OF AGE) (MEAN VALUES)	GROUP II (50) (YEARS OF AGE) (MEAN VALUES)
Before	1.1958 gm	1.0031 gm
After	1.0513	.9039
Amount Lost	.1445	.0992
Per Cent Water Loss	12.1012	9.6895
T-value	2.6049	2.3095

TABLE II

INCINERATION AT 2000° F. FOR 6 HOURS

	GROUP I (15) (YEARS OF AGE) (MEAN VALUES)	GROUP II (50) (YEARS OF AGE) (MEAN VALUES)
Before	6.4727 gm	5.8781 gm
After	5.0992	4.4505
Amount lost	1.3735	1.4276
Per Cent Organic Material Lost	21.2991	24.1859
T-value	3.8257	3.3928

CHAPTER IV

DISCUSSION

In the dehydration part of this investigation, it appears that the process of dehydration requires time and may proceed at different rates for different age groups of teeth. In Group I, the loss of water appears to have proceeded at a faster rate since the difference between the additional loss of water between one hundred ninety-two and two hundred eighty-eight hours was insignificant while in Group II it was significant. Thus the older teeth require a greater drying period than the young teeth. However, if one examines the actual weights at ninety-six, one hundred ninety-six and two hundred eighty-eight hours, one finds that the differences between these readings are insignificant in the older group and significant in the young group, and thus does not support the above statement.

With regard to the problem existing between the two groups in original weights, it becomes apparent that either in random selection the two groups differ by chance, or the difference can be explained in the following manner: Group I consists mainly of premolars from white children while Group II consists of premolars and incisors from Negro adults.

Thus, the investigator feels that initially racial and type of tooth variables have been hidden in the random selection process and have thus accounted for the difference in the two groups.

In both parts of this investigation, the net loss of water and organic material in Groups I and II were found to be significant.

From the data in Table I, it can be seen that the younger group lost more water than the older group and the difference based on per cent is highly significant. This is not at all surprising since teeth, like connective tissue, show marked age changes consisting of mineralization and decreased cellular content resulting in decreased water content.

The above statement appears to be supported by the information in Table II. With incineration, it has been shown that the older group lost more organic material than the younger group, based on per cent.

The question of gravimetric error in the accumulation of the data is present and one cannot make a statement denying the possibility of such occurrence. However, the investigator feels relatively secure in the weighing procedure because no reversals in weights were apparent. Several

teeth in both groups were eliminated from the final data because during dehydration, the teeth became very brittle and fractured. why eliminate?

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to demonstrate whether or not aging in a tooth is accompanied by water loss and a change in organic material content.

The procedures used were a physical drying off of water with mild heat and the ashing of teeth with severe heat.

The results expressed in Tables 1 and 2 showed a greater per cent loss of water in the young group and a greater per cent loss of organic material in the older group.

In the final analysis, based upon the relative values express in Tables 1 and 2 and under the conditions elaborated upon in the discussion, the following statements can be made:

A) There is a higher water content in young teeth than old.

B) There is a higher organic content in old teeth than young.

APPENDIX

RAW DATA FOR DEHYDRATION (ACTUAL VALUE)

GROUP I (15)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V.7
Tooth #	Orig. Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
1.	1.0116 gm	.8861 gm	.1255 gm	.8860 gm	.0001 gm	.8849 gm	.0011 gm
2.	1.2011	1.0660	.1351	1.0660	.0000	1.0653	.0007
3.	1.2065	1.0641	.1424	1.0631	.0010	1.0599	.0032
4.	1.1483	1.0132	.1351	1.0132	.0000	1.0094	.0038
5.	1.1134	.9774	.1360	.9721	.0053	.9720	.0001
6.	.9396	.8368	.1028	.8215	.0053	.8213	.0002

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP I (15)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
7	.9732 gm	.8637 gm	.1095 gm	.8592 gm	.0045 gm	.8590 gm	.0002 gm
8	1.1641	1.0255	.1386	1.0255	.0000	1.0233	.0022
9	1.1793	1.0405	.1388	1.0400	.0005	1.0396	.0004
10	1.4320	1.2734	.1586	1.2730	.0004	1.2691	.0039
11	1.4427	1.3097	.1330	1.3094	.0003	1.3082	.0012
12	1.2372	1.0823	.1549	1.0805	.0018	1.0792	.0013
13	1.2181	1.0661	.1520	1.0650	.0011	1.0644	.0006
14	1.5289	1.3619	.1670	1.3613	.0006	1.3588	.0025

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP I (15)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
15	1.5449 gm	1.3529 gm	.1920 gm	1.3528 gm	.0001 gm	1.3497 gm	.0031 gm
16	1.2391	1.0758	.1633	1.0758	.0000	1.0741	.0017
17	1.3856	1.2042	.1814	1.2041	.0001	1.2032	.0009
18	1.1593	1.0029	.1564	1.0020	.0008	1.0015	.0005
19	1.1484	.9798	.1686	.9798	.0000	.9785	.0013
20	1.5359	1.3115	.2244	1.3115	.0000	1.3068	.0047
21	1.4627	1.2434	.2193	1.2434	.0000	1.2397	.0037

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP I (15)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
22	1.6125 gm	1.4294 gm	.1831gm	1.4294 gm	.0000 gm	1.4291 gm	.0003 gm
23	1.6064	1.4447	.1617	1.4445	.0002	1.4421	.0024
24	1.3383	1.1935	.1448	1.1934	.0001	1.1892	.0042
25	1.3622	1.2163	.1459	1.2159	.0004	1.2148	.0011
26	1.0113	.8745	.1368	.8709	.0036	.8708	.0001
27	1.0149	.8909	.1240	.8879	.0030	.8879	.0000
28	1.1989	1.0605	.1384	1.0604	.0001	1.0599	.0005
29	1.2041	1.0713	.1328	1.0713	.0000	1.0698	.0015

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP I (15)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
30	.9366 gm	.8290 gm	.1076 gm	.8246 gm	.0044 gm	.8240 gm	.0006 gm
31	.8204	.7270	.0934	.7219	.0051	.7218	.0001
32	.8999	.7811	.1188	.7804	.0007	.7796	.0008
33	.8913	.7807	.1106	.7800	.0007	.7798	.0002
34	1.1421	1.0049	.1372	1.0049	.0000	1.0034	.0015
35	1.0750	.9814	.0936	.9764	.0050	.9762	.0002
36	1.2136	1.0828	.1308	1.0818	.0010	1.0794	.0024
37	1.2373	1.1050	.1323	1.1047	.0003	1.1044	.0003
38	1.0298	.9197	.1101	.9156	.0041	.9151	.0005

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP I (15)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr Dry Wgt.	Diff.	192 hr Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
39	.9621 gm	.8640 gm	.0981 gm	.8585 gm	.0055 gm	.8578 gm	.0007 gm
40	1.3096	1.1491	.1605	1.1490	.0001	1.1461	.0029
41	1.2732	1.1297	.1435	1.1285	.0012	1.1267	.0018
42	1.0223	.8995	.1288	.8957	.0038	.8943	.0014
43	.9872	.8791	.1081	.8711	.0080	.8709	.0002
Sum (X)	51.4209	45.3413	6.0696	45.2770	.0692	45.2066	.0610
Sum $(X)^2$	63.2704	49.2053	.8942	49.0933	.0003	48.9315	.0002
Mean	1.1958	1.0545	.1412	1.0530	.0016	1.0513	.0014
Variance	.0424	.0332	.0009	.0338	.000005	.0033	.000002
Std. Dev.	.2058	.1823	.0299	.1838	.0021	.1829	.0013

ADDITIONAL DEHYDRATION DATA

GROUP I (15)

	V_1 (Original Weight)	V_6 (Wgt. After 288 Hr. Dehydration)	V_8 (Difference)	V_9 (% Change)
Sum (X)	51.4209	45.2066	6.2143	520.3520
Sum $(X)^2$	63.2704	48.9315	.9356	6366.1900
Mean	1.1958	1.0513	.1445	12.1012
Variance	.0437	.0345	.0008	1.6498
Std. Dev.	.2058	.1829	.0291	1.2845

DEHYDRATION

PAIRED SAMPLES T-TEST

GROUP I (15)

V_2	V_4	T-VALUE
Weight after 96 hrs. of dehydration	Weight after 192 hrs. of dehydration	2.9629
V_4	V_6	
Weight after 192 hrs. of dehydration	Weight after 288 hrs. of dehydration	5.9613
V_5	V_7	
Additional loss of H_2O after 192 hrs. dehydration	Additional loss of H_2O after 288 hrs. dehydration	.4122

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP II (50)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
1.	1.7638gm	1.5480gm	.2158gm	1.5463gm	.0017gm	1.5461gm	.0002gm
2	1.7801	1.5789	.2012	1.5769	.0020	1.5765	.0004
3	1.8555	1.5989	.2566	1.5980	.0009	1.5973	.0007
4	1.0316	.9195	.1121	.9184	.0011	.9160	.0024
5	1.0674	.9431	.1243	.9425	.0006	.9394	.0031
6	.8199	.7011	.1188	.6999	.0012	.6984	.0015
7	1.3881	1.1414	.2467	1.1411	.0003	1.1401	.0010
8	1.2551	1.1269	.1282	1.1199	.0070	1.1187	.0012
9	.6751	.6409	.0342	.6403	.0006	.6398	.0005

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP II (50)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
10	.5568gm	.5080gm	.0488gm	.5070gm	.0010gm	.5065gm	.0005gm
11	.5772	.5255	.0517	.5249	.0006	.5237	.0012
12	.8726	.7961	.0765	.7941	.0020	.7940	.0001
13	.9445	.8541	.0904	.8538	.0003	.8534	.0004
14	.8008	.7350	.0658	.7349	.0001	.7348	.0001
15	1.3901	1.2819	.1082	1.2807	.0012	1.2798	.0009
16	1.7511	1.6024	.1487	1.6008	.0016	1.6005	.0003
17	1.0559	.9651	.0908	.9648	.0003	.9621	.0027
18	1.4448	1.3207	.1241	1.3205	.0002	1.3194	.0011

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP II (50)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
19	.9484gm	.8747gm	.0737gm	.8741gm	.0006gm	.8738gm	.0003gm
20	.3884	.3265	.0619	.3248	.0017	.3239	.0009
21	.7129	.3539	.0590	.3528	.0011	.3523	.0005
22	.5875	.5379	.0469	.5368	.0011	.5357	.0011
23	.6431	.5769	.0662	.5735	.0034	.5731	.0004
24	.4603	.4256	.0347	.4160	.0096	.4160	.0000
25	.4326	.3917	.0409	.3916	.0001	.3910	.0006
26	.5372	.4850	.0522	.4849	.0001	.4849	.0000
27	.5422	.4863	.0559	.4863	.0000	.4860	.0003

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP II (50)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
28	1.2216gm	1.0048gm	.2168gm	1.0036gm	.0012gm	1.0029gm	.0007gm
29	.9599	.8710	.0889	.8664	.0046	.8660	.0004
30	1.0684	.9793	.0891	.9740	.0053	.9738	.0002
31	.5262	.4749	.0513	.4720	.0029	.4718	.0002
32	.7970	.7222	.0748	.7204	.0018	.7203	.0001
33	.7998	.7339	.0659	.7323	.0016	.7316	.0007
34	.7997	.7286	.0711	.7274	.0012	.7270	.0004
35	.5366	.4841	.0525	.4830	.0011	.4825	.0005
36	.4542	.4129	.0413	.4120	.0009	.4105	.0015

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP II (50)

	Variable 1	V. 2	V. 3	V. 4	V. 5	V. 6	V. 7
Tooth #	Orig. Wgt.	96 hr. Dry Wgt.	Diff.	192 hr. Dry Wgt.	Add. Loss of H_2O	288 hr. Dry Wgt.	Add. Loss of H_2O
37	1.1659gm	1.0846gm	.0813gm	1.0843gm	.0003gm	1.0841gm	.0002gm
38	1.1411	1.0666	.0745	1.0659	.0007	1.0652	.0007
39	.7956	.7375	.0581	.7375	.0000	.7370	.0005
40	.7885	.7330	.0555	.7322	.0008	.7321	.0001
41	1.7775	1.6280	.1495	1.6258	.0022	1.6255	.0003
42	1.6392	1.5041	.1351	1.5032	.0009	1.5026	.0006
43	1.3895	1.2777	.1118	1.2777	.0000	1.2772	.0005
44	1.3035	1.2005	.1030	1.2002	.0003	1.2001	.0001
45	1.3994	1.2813	.1181	1.2806	.0007	1.2801	.0005

RAW DATA FOR DEHYDRATION
(ACTUAL VALUE)

GROUP II (50)

Tooth #	Variable 1 Orig. Wgt.	V. 2 96 hr. Dry Wgt.	V. 3 Diff.	V. 4 192 hr. Dry Wgt.	V. 5 Add. Loss of H_2O	V. 6 288 hr. Dry Wgt.	V. 7 Add. Loss of H_2O
Sum(X)	45.1384 gm	40.7708 gm	4.3729 gm	40.2041 gm	.0669 gm	40.6735 gm	.0306 gm
$Sum(X)^2$	52.8976	42.9650	.5636	42.1562	.0003	42.7933	.00004
Mean	1.0031	.9060	.0972	.8934	.0015	.9039	.0006
Variance	.1732	.1370	.0032	.1417	.000004	.1371	.0000005
Std. Dev.	.4162	.3701	.0561	.3765	.0019	.3702	.0007

ADDITIONAL DEHYDRATION DATA

GROUP II (50)

	V_1 (Original Weight)	V_6 (Wgt. After 288 Hr. Dehydration)	V_8 (Difference)	V_9 (% Change)
Sum (X)	45.1384	40.6735	4.4690	436.0270
Sum $(X)^2$	52.8976	42.7933	.5821	4502.9100
Mean	1.0031	.9039	.0992	9.6895
Variance	.1732	.1371	.0032	6.3189
Std. Dev.	.4162	.3702	.0562	2.5138

DEHYDRATION

PAIRED SAMPLES T-TEST

GROUP II (50)

V_2	V_4	T-VALUE
Weight after 96 hrs. of dehydration	Weight after 192 hrs. of dehydration	1.1351
V_4	V_6	
Weight after 192 hrs. of dehydration	Weight after 288 hrs. of dehydration	.9434
V_5	V_7	
Additional loss of H_2O after 192 hrs. dehydration	Additional loss of H_2O after 288 hrs. dehydration	2.5774

INDEPENDENT SAMPLES T-TEST

Group I	V_1	T value = 2.7340
Group II	V_2	T value = 2.3694
	V_3	T value = 4.5570
	V_4	T value = 2.5073
	V_5	T value = .2854
	V_6	T value = 2.3517
	V_7	T value = 3.3527

T-VALUES ON DEHYDRATION

BETWEEN GROUPS I AND II

VARIABLE	T-VALUE
(1) Original Weight	2.7340
(6) Net Weight after 288 hr. dehydration	2.3517
(8) Difference	4.7141
(9) Total % Change	5.6274

RAW DATA FOR INCINERATION
(ACTUAL VALUES)

GROUP I (15)

	V_1	V_2	V_3	V_4	V_5	V_6
Cruc. #	Cruc. Wt.	Cruc. & Sample	Sample Wt.	Cruc. & Sample After Incine.	Net Sample	Total Loss
1	8.9390	14.8319	5.8929	13.5833	4.6443	1.2486
2	9.8384	16.4959	6.6575	15.1311	5.2927	1.3648
3	9.8859	17.0290	7.1431	15.5692	5.6833	1.4598
4	10.0625	17.7111	7.6486	16.1746	6.1121	1.5365
5	10.1251	16.3920	6.2651	14.9997	4.8746	1.3905
6	9.6831	15.4867	5.8036	14.1846	4.5015	1.3021
7	7.7200	13.6179	5.8979	12.3056	4.5856	1.3126
Sum (X)	66.2540	111.5630	45.3087	101.9480	35.6941	9.6149

RAW DATA FOR INCINERATION
(ACTUAL VALUES)

GROUP I (15)

	V_1	V_2	V_3	V_4	V_5	V_6
Cruc. #	Cruc. Wt.	Cruc. & Sample	Sample Wt.	Cruc. & Sample After Incine.	Net Sample	Total Loss
Sum $(X)^2$	631.5630	1789.6900	296.2920	1495.1000	184.2930	13.2654
Mean	9.4649	15.9375	6.4727	14.5640	5.0992	1.3736
Variance	.7464	1.9433	.5039	1.7203	.3805	.0098
Std. Dev.	.8639	1.3940	.7099	1.3116	.6168	.0989

RAW DATA FOR INCINERATION
(PER CENT)

GROUP I (15)

	V_3 Sample Wgt.	V_5 Sample Wgt. After Incineration	V_7 % Loss
	5.8929	4.6443	21.1882
	6.6575	5.2927	20.5002
	7.1431	5.6833	20.4365
	7.6486	6.1121	20.0886
	6.2651	4.8746	22.1944
	5.8036	4.5015	22.4361
	5.8979	4.5856	22.2554
Sum (X)	45.3087	35.6941	149.0930
Sum $(X)^2$	296.2920	184.2930	3181.4200
Mean	6.4727	5.0992	21.2991
Variance	.5039	.3805	.9784
Std. Dev.	.7099	.6168	.9891

RAW DATA FOR INCINERATION
(ACTUAL VALUES)

GROUP II (50)

	V_1	V_2	V_3	V_4	V_5	V_6
Cruc. #	Cruc. Wt.	Cruc. & Sample	Sample Wt.	Cruc. & Sample After Incine.	Net Sample	Total Loss
1	6.1400	12.8080	6.6680	11.2328	5.0928	1.5752
2	9.0129	14.0754	5.0625	12.9222	3.9093	1.1532
3	10.1856	16.8813	6.6957	15.1493	4.9637	1.7320
4	8.2915	12.8653	4.5738	11.7660	3.4745	1.0993
5	9.7288	15.9305	6.2017	14.3650	4.6362	1.5655
6	10.3317	15.3155	4.9838	14.1649	3.8332	1.1506
7	9.2612	16.2224	6.9612	14.5053	5.2441	1.7171

RAW DATA FOR INCINERATION
(ACTUAL VALUES)

GROUP II (50)

	V_1	V_2	V_3	V_4	V_5	V_6
Cruc. #	Cruc. Wt.	Cruc. & Sample	Sample Wt.	Cruc. & Sample After Incine.	Net Sample	Total Loss
Sum (X)	62.9517	104.0980	41.1467	94.1055	31.1538	9.9929
Sum $(X)^2$	578.5910	1564.1700	247.7010	1278.5000	141.6180	14.7425
Mean	8.9931	14.8712	5.8781	13.4436	4.4505	1.4276
Variance	2.0766	2.6833	.9561	2.2300	.4945	.0795
Std. Dev.	1.4412	1.6381	.9778	1.4933	.7032	.2820

RAW DATA FOR INCINERATION
(PER CENT)

GROUP II (50)

	V_3	V_5	V_7
	Sample Wgt.	Sample Wgt. After Incineration	% Loss
	6.6680	5.0928	23.6234
	5.0625	5.9093	22.7793
	6.6957	4.9637	25.8673
	4.5738	3.4745	24.0347
	6.2017	4.6362	25.2431
	4.9838	3.8332	23.0868
	6.9612	5.2441	24.6667
Sum (X)	41.1467	31.1538	169.3010
Sum $(X)^2$	247.6010	141.6180	4102.4100
Mean	5.8781	4.4505	24.1859
Variance	.9561	.4945	1.2836
Std. Dev.	.9778	.7032	1.1330

T-VALUES ON INCINERATION DATA

BETWEEN GROUPS I AND II

VARIABLE		T-VALUE
(1)	Crucible Weight	.7429
(2)	Crucible and Sample	1.3116
(3)	Sample Weight	1.3019
(4)	Crucible & Sample (Incinerated)	1.4914
(5)	Net Sample	1.8346
(6)	Total Loss of Sample	.4781
(7)	Percentage Loss	5.0784

BIBLIOGRAPHY

Barnfield, W.C., Width and Length of Collagen Fibrils During the Development of Human Skin, in Granulation Tissues, and in the Skin of Adult Animals, J. Geront., 10:13, 1955.

Beust, T.B., Physiological Changes in the Dentin, J. Dental Research, 11:267, 1931.

Beust, T.B., Posteruptive Changes in the Maturation of Teeth, J.A.D.A., 18:2168, 1931.

Beust, T.B., Demonstration of Sclerosis of Dentin in Tooth Maturation and Caries, Dent. Cosmos, 76:305, 1934.

Bhussry, B.R., Changes in the Density and Nitrogen Content of Enamel with Age, Proceedings, 25-year Celebration, Univ. of Rochester Dental Research Fellowship Program, 65, Univ. of Rochester, 1957.

Bodecker, C.F., and W. Refkowitz, Concerning the "Vitality" of the Calcified Dental Tissues, J. Dental Research, 16:493, 1937.

Bodecker, C.F., and W. Lefkowitz, Further Observations on the Vital Staining of Dentin and Enamel, J. Dental Research, 25:387, 1946.

Bradford, E.W., The Maturation of the Dentine, Brit. Dental J., 105:212, 1958.

Brudevold, F., Changes in Enamel with Age, Proceedings, 25-year Celebration, Univ. of Rochester Dental Research Fellowship Program, 185, 1957.

Chilton, N.W., Design and Analysis in Dental and Oral Research, J.B. Lippincott Company, Philadelphia, 1967.

Clausen, F., Influence of Age on Connective Tissue Hexosamine and Hydroxypeoline in Human Aorta, Myocardium and Skin, Lab. Invest., 11:229, 1962.

Clausen, F., Influence of Age on Connective Tissue, Uronic Acid and Uronic Acid -- Hydroxyproline Ratio in Human Aorta, Myocardium and Skin, Lab. Invest., 11:1340, 1962.

Fischer, A.K., Wade, D.M., Chalup, M.J., and Nash, L.L., Further Studies on the Nitrogen Content of Dental Pulp, I. Dental Research, 37:214, 1958.

Fish, E.W., An Experimental Investigation of Enamel, Dentine and the Dental Pulp, John Bale and Sons, Ltd., London, 1933.

Gustafson, A., Age Determination on Teeth, J.A.D.A., 21:45, 1950.

Hill, T.J., Pathology of the Dental Pulp, J.A.D.A., 21:820, 1934.

Hodge, H.C., Lipids in the Tooth Pulp, Proc. Soc. Exp. Biol., 35:53, 1936.

Kronfeldt, R., Histopathology of the Teeth and Surrounding Structures, 2nd Edition, Lea and Febiger, Philadelphia, 1939.

Losee, F.L., Leopold, R.F., and Hess, W.C., Dentinal Protein, J. Dental Research, 30:565, 1951.

Miller, W.D., Micro-Organisms of the Human Mouth, 156, S.S. White Dental Mfg. Co., Philadelphia, 1890.

Nalbandian, J., Microstructural Characteristics of Human Dentin with Special Reference to Aging, Thesis, Harvard School of Dental Medicine, Boston, Mass., 1958.

Nalbandian, J., Age Changes in Human Teeth, J. Dental Research, 38:681, 1959.

Nalbandian, J., F. Gonzales, and R.F. Sognnaes, Sclerotic Age Changes in Root Dentin of Human Teeth as Observed by Optical, Electron and X-Ray Microscopy, J. Dental Research, 39:598, 1960.

Riedesel, M.L., and Fischer, A.K., Nitrogen Content of Dental Pulp, J. Dental Research, 33:632, 1954.

Ring, J.R., Age Changes in Oral Subepithelial Connective Tissue in Aging -- Some Social and Biological Aspects, Edit. Nathan W. Schock, Harn-Schafer Co., Baltimore, 1960.

Scott, D.B., H. Kaplan and R.W. Wyckoff, Replica Studies of Changes in Tooth Surfaces with Age, J. Dental Research, 28:31, 1949.

Seltzer, S., and Bender, I.B., The Dental Pulp, J.B. Lippincott Company, Philadelphia, 1965.

Sicher, H., Orban's Oral Histology and Embryology, 5th Edition, C.V. Mosby Company, St. Louis, 1962.

Sinex, F.M., Biochemistry of Aging, Perspect. Biol. Med., 9:208, 1965.

Sobel, H., Zutrauen, H.A., and Marmorston, J., The Collagen and Hexosamine Content of the Skin of Normal and Experimentally Treated Rats, Arch. Biochem. and Biophys., 46:221, 1953.

Sobel, H., Harmorston, J., and Moore, F. J., Collagen and Hexosamine Content of the Femurs of Rats, Proc. Soc. Exp. Biol. and Med., 87:436, 1954.

Stack, M.V., and Fearnhead, R.W., Tooth Enamel, The Williams and Wilkins Company, Baltimore, 1965.

Yoon, S.H., Brudevold, F., Smith, F.A., and Gardner, D.E., Fluoride, Calcium, Phosphate, Ash, and Water Content of Human Dental Pulps, J. Dental Research, 44:696, 1965.

Zander, H.A., and Hurzeler, B., Continuous Cementum Apposition, J. Dental Research, 37:1035, 1958.

APPROVAL SHEET

The thesis submitted by Edward F. Kastelic has been read and approved by members of the Department of Oral Biology.

The final copies have been examined by the director of thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

May 23 1969
Date

Patrick D. Tobb
Signature of Advisor