

A Chronological Account of the Bolton-Brush Growth Studies

In Search of Truth for the Greater Good of Man
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Overview

This account begins as all other significant research undertakings always begin: with researchers and their ideas preceding the research. Often, when opportunity is provided, men who are energetic, intelligent, committed, resolute, visionary, and interested in investigating man, significant contributions to humanity are possible. This is obviously true for those in the Bolton-Brush Growth Studies, beginning with the strong leadership of Dr. T. Wingate Todd and Dr. B. Holly Broadbent.

1907

A history of the Studies start with Dr. T. Wingate Todd (1885- 1938) who in 1907, upon graduation with honors from the University of Manchester Medical School, subsequently served for four years there as a demonstrator and lecturer in surgical anatomy. He cultivated a lifelong interest in anthropology and developed interests in pediatrics and radiology.

1912

In this year Dr. Carl Hamann was named the Dean of the Western Reserve Medical School, and he requested Sir Arthur Keith, a world renowned anatomist and anthropologist, to recommend his own replacement in Anatomy. Dr. Keith suggested Dr. Todd. Thus, in 1912, Dr. Todd, (Figure 1) was enticed to come to the United States to accept appointment in the Department of Anatomy of the School of Medicine in Western Reserve University as the first Henry Wilson Payne Professor of Anatomy. In 1915 Dr. Todd interrupted his teaching to join the Canadian army during World War I.

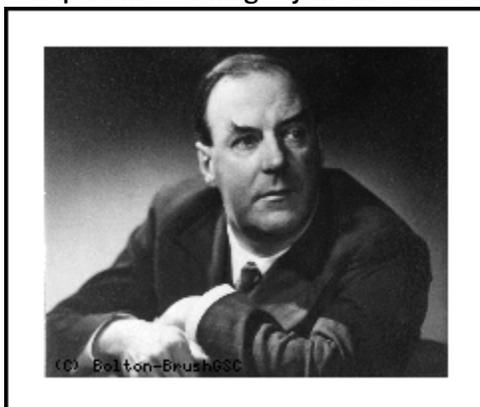


Figure 1

1918

Dr. Todd returned to teaching at his former post. He continued and expanded his early interests in the areas of comparative and human anatomy with a special emphasis on pediatric anatomy. During

the following years he expanded and developed a superb collection of human and primate skeletal materials in the anatomical museum initiated under his predecessor, Dr. Hamann. This was later to be known as the Hamann-Todd Collection comprising literally thousands of human and primate skeleton. It is now housed and actively utilized at the Cleveland Museum of Natural History. The human material of the collection resulted from Todd's keen interest in human anatomy, especially for children. In search of more and more knowledge in this area, he and others convinced the Ohio General Assembly to pass legislation permitting local hospitals, the Cleveland Workhouse, and undertakers to donate cadavers to medical schools for research and teaching. For a dozen years thereafter he was able to study the cadavers of unclaimed pauper children of Cleveland. In these studies, in which it is said he studied as closely and tenderly as he did the living, the results were rewarding—resulting in numerous publications—but to him also limited and frustrating. Most of the children had succumbed to diseases such as tuberculosis.

Todd realized that disease had distorted and retarded the body growth processes and, therefore, results based on dissecting room material, had limited applications to normal growth and development. He spoke of this often, apparently from frustration, as he felt science knew more about sickness and abnormality than health. As a result, he felt medicine taught mainly only the recognition of established disease, and that the teaching of normal growth was based improperly on non-normal material.

In recognition of these limitations Todd desired:

...the opportunity to investigate developing organs under favorable circumstances, and anatomy plus radiography and observations of healthy children can provide this opportunity...forward from the cradle, not backward from the morgue.

1924

In this year, a development which would later prove very significant began with the appointment of Dr. B. Holly Broadbent, Sr., (1894-1977) as a research fellow in the Department of Anatomy under Dr. Todd.

Dr. Broadbent, in 1914 while working in a drafting room of Wellman, Sever & Morgan Co. (running a shop, preparing machine plans), met Dr. Varney Barnes through his son Dick, who was a Boy Scout. This association led to an interest in dentistry, and in 1916 he entered the Western Reserve University Dental School. Studying anatomy under Dr. Todd, Holly Broadbent began to develop his life-long interest in facial morphology and growth. In 1919 he graduated from Dental School and then worked with Dr. W. E. Newcomb as a clinical associate until 1921. He married Bernice Mathews and traveled to California to attend the famous Angle School of Orthodontia, from which he graduated in 1924.

In 1924, Dr. Broadbent, now an orthodontist, had become interested in dentofacial research. One of his first contributions was the idea to include a metric scale on Dr. Todd's craniostat. This device was used to hold a skull in a fixed position, permitting direct measurements of dentofacial structures on dry skulls (i.e., the craniometer).

1925

Dr. Broadbent, with Dr. Todd's help, extended the capabilities of the craniometer by adding an x-ray film hold (i.e., the roentgenographic craniometer). This made possible precise standardization of cranial x-rays using dry skulls.

During this time, in his orthodontic practice, Dr. Broadbent had been using non-standardized lateral head x-rays of his patients, obtained from the firm of Hill and Thomas, to help in diagnosis by determining facial and soft tissue relationships. However, it was obvious that without standardization these lateral x-rays could not meaningfully demonstrate changes through time.

1926

In this year, Dr. Broadbent adapted the roentgenographic craniometer, previously used for holding only dry skulls in a fixed position, to hold the head of a living subject while precise lateral and posteroanterior radiographs were taken (i.e., the roentgenographic cephalometer). The prototype was made of wood and a short time later remade in metal in the Department of Anatomy machine shop, thus introducing a standardized piece of equipment, and the procedure to use it, permitting precise, reproducible, comparable x-rays of a child's growing face at intervals on through to adult life. Detailed internal study of the growing head and face in individual children through time had now become possible (Figure 2).

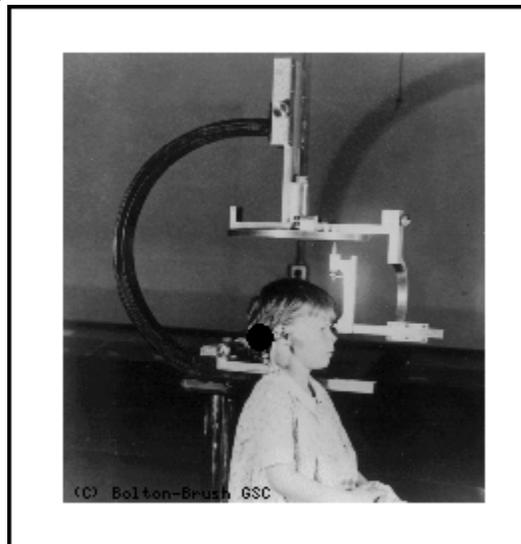


Figure 2

Dr. Broadbent demonstrated that:

1. The application of precise methods of measurement used by the physical anthropologist in orthodontic practice was a decided advantage toward a more scientific solution of orthodontic problems.
2. By means of a headholder and a standardized roentgenographic technique, it is possible to make accurate determinations of changes in the living head resulting from growth or orthodontic treatment.
3. Such a technique permitted study and measurement of these changes in the same individual. This eliminated the uncertainty of measuring changes by comparison of dimensions of different individuals at successive ages.

4. This roentgenographic technique registered the craniometric landmarks of the face, cranial base of the living head which, heretofore, had only been measured on dead skulls with the craniostat.
5. Present (then) standards compiled from measurements of the dry skulls of children were largely a measure of inappropriate material. A dead child could represent an anatomically defective one because growth could have been affected by whatever condition previously existed.
6. This craniometric technique has the decided advantage of not requiring determination of hard-tissue landmarks deep to the covering of soft tissues of uncertain thickness.
7. Such roentgenograms reveal areas in the cranial base that show little change between certain ages. These areas offer more stable reference structures for relating x-ray tracings and afford a very accurate base for measuring changes in the teeth, jaws and face.

1926 **The Early Studies**

In this year and continuing into 1927 Dr. Todd, working out of the Department of Anatomy with a small grant from the Cleveland Health Council and with the approval of the Cleveland Board of Education, conducted a limited study (600 children) on the health of well-developed children in the Stearns Road Grade School. (Unfortunately these children were lost to follow-up due to a temporary interruption of funds in 1928.)

1927

The above mentioned project provided impetus for continuing exploratory, longer-term studies into the characteristics of a healthy child, and a three year exploratory study was begun. Todd arranged summer exams for ages 6-14 through the Cleveland Board of Education and the staffs of two public schools. These exams were conducted as a health "contest" among the children, the reward being a short holiday at a summer camp under the auspices of the Cleveland Welfare Federation and the local press.

The study, involving more than 200 children and conducted with the assistance of graduate students and medical students, consisted of standard anthropometric exams (external body measures), an assessment of present health, radiographs of 6 areas of the body, various behavioral responses and a recording of familial background. Children with problems were referred to family physicians. The results of the studies were reported to the administrators and teachers who had helped in conducting the study, and the winners went off to camp.

1928

This year was significant in many ways. The initial summer examination study was again conducted with groups of children from other schools plus some of the original group recalled for a second examination. Thus at the end of the second summer just over 700 examinations of individual children had been conducted.

Also in 1928, the soundness and worth of the project was recognized locally and Nationally. It was realized that the nature of human growth processes were clarified when data collected consecutively was added to school records, parental observations and examinations by the family physician. In this regard new funds for conducting studies such as these now became available. Several philanthropic organizations (Laura Spelman Rockefeller Memorial, General Education Board of the Rockefeller

Foundation, U.S. Public Health Service) matched community grants-in-aid for the longitudinal study of healthy children across the United States in order to improve the National standards for reference of growth. Community funds were given notably by the Brush Foundation and the Bolton Fund, among others (Cleveland Foundation, Associated Foundations, etc.).

The year of 1928 was notable, further, in regard to the input of Charles Francis Brush (1849-1929). This man (Figure 3) was a world famous inventor-genius responsible for development, for example, of the arc light, open coiled dynamo, storage battery, and liquid air. His electric company later was consolidated to form the General Electric Company. He enjoyed lifelong interests in such diverse subjects as electricity, gravity, outer space, and race betterment. Following his son's untimely death, he created in his memory the Brush Foundation by establishing a research fund of \$500,000. The mission was research and education toward "the end that children shall be begotten only under conditions which make possible a heritage of mental and physical health, and a favorable environment."

In October of 1928, the first research program undertaken by the Brush Foundation was entitled "Health Inquiry" under the direction of T. Wingate Todd. The purpose was to search out the "normal developmental growth process." Dr. Todd was chosen by Mr. Brush as a logical choice (described as: a skeletal anatomist, pediatrician, brave, persuasive, broadly cultivated, contagiously enthusiastic, and with demonic energy) for the first Director in addition to his duties as Professor of Anatomy in the School of Medicine.



Figure 3

THE BRUSH FOUNDATION

An Excerpt from the Deed of Gift of

CHARLES FRANCIS BRUSH



WHEREAS, my beloved son, Charles Francis Brush, Jr., who died on May 29, 1927, was devoting his life to scientific research for the advancement of human knowledge; and

WHEREAS, in my opinion the most urgent problem confronting the world today is the rapid increase of population which threatens to over-crowd the earth in the not distant future, with resultant shortage of food and lower standards of living, which must certainly lead to grave economic disturbances, famines and wars, and threaten civilization itself; and

WHEREAS, beneficent scientific research has contributed toward the prolongation of life and the preservation of the weak and the unfit, who under former conditions could not have survived nor added descendants to the race; and

WHEREAS, I believe that scientific knowledge cannot safely be used for these humane objects, unless it be used at the same time to improve the quality and reasonably limit the numbers of those who are born into the world;

NOW, THEREFORE, out of my belief that such restriction of the increase of population, and the betterment of the human stock are fundamental to the well-being of humanity, I have established a Foundation for the benefit of mankind and as a memorial to my beloved son, Charles Francis Brush, Jr.

The income of this trust shall be used by the Board of Managers to finance efforts contributing toward the betterment of the human stock, and toward the regulation of the increase of population, to the end that children shall be begotten only under conditions which make possible a heritage of mental and physical health, and a favorable environment. These purposes include the furtherance of scientific research in the field of eugenics and in regulation of the increase of population; the education of the people to the importance of the betterment of the stock and to the economic and social evils which result from too great increase of population; and any activities which shall serve the intent set forth in this instrument and its preamble.



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(C) Bolton-Brush GSC

Also in 1928 it had become clear that Dr. Broadbent's work was making a unique contribution to precision radiography. Discussions of this new technique with the Honorable Frances Payne Bolton had already began in 1926. This lady was well known for her lifetime devotion to public service (later serving in the Congress of the United States), philanthropy and interest in normal childhood growth (Figure 4). Subsequently, encouraged by Dr. Broadbent and Dr. Todd, Frances Payne Bolton and her son established the Charles Bingham Bolton Fund in October of 1928. It was designed to subsidize a period of study covering five years as an independent but coordinated study in conjunction with the Brush Inquiry. The intent of the study was to determine what occurred in the facial skeleton and dental areas during growth and development. This major effort subsequently became known as the Bolton Study of the Development of the Face of the Growing Child. Support continued well beyond the initial five year period, with son Charles Bingham Bolton (Figure 5) participating as a prominent research associate. It was then the largest privately endowed research program in all of dentistry. Mrs. Bolton also encouraged other comparable studies over the years by providing some 40

cephalometers to many institutions and researchers throughout the United States as well as abroad (Table I).



Figure 4

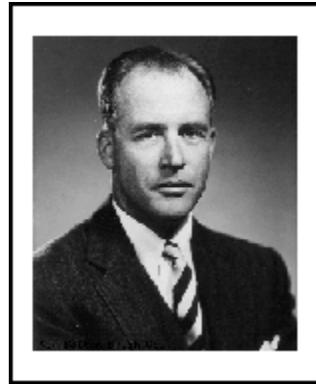


Figure 5

1929

On May 29, 1929 it was announced to the public that a Cleveland center for the longitudinal study of children was to be established and to be named the Brush Inquiry.

It was hoped that the study of living children, with growth, development and maturation documented at successive intervals through the childhood years, would show why some thrived and others did not. The aim was more than saving children from disease, it was to determine how to confer on them such physical and mental superiority as to ensure life and happiness. The year 1929 was also historic in that in May, Dr. Broadbent presented a paper demonstrating the cephalometric technique which, along with some of his other papers and presentations, predate the landmark publication "A New X-Ray Technique and its Application to Orthodontia" (1931, Figure 6).

TABLE I
BOLTON ROENTGENOGRAPHIC CEPHALOMETERS SOLD OR DONATED TO INSTITUTIONS OR
INDIVIDUALS
Institutions

1. Army Medical Center, Army Medical Department and Graduate School, 1949, Washington, D.C.
2. Baylor University, 1963-1964, Dallas, Texas
3. University of Buffalo, 1953, Buffalo, New York
4. University of California, 1942, San Francisco, California
5. Eastman Dental Dispensary, 1960, Rochester, New York
6. Albert Einstein Medical Center, 1959, Philadelphia, Pennsylvania
7. Forsyth Infirmary attached to Harvard University, 1940, Boston, Massachusetts
8. Guy's Hospital Dental Department, 1955, London, England
9. Hebrew University, 1962, Jerusalem, Israel
10. Hillman Hospital, 1945, Birmingham, Alabama
11. University of Illinois, 1932, Chicago, Illinois
12. University of Indiana, 1960, Indianapolis, Indiana
13. University of Manitoba, 1960, Winnipeg, Manitoba, Canada
14. Marquette University, 1957, Milwaukee, Wisconsin
15. Mayo Clinic, 1958, Rochester, Minnesota
16. College of Medical Evangelists, Loma Linda University, 1955, Loma Linda, California
17. University of Melbourne, 1940, Melbourne, Victoria, Australia
18. University of Minnesota, 1954, Minneapolis, Minnesota
19. Mount Sinai Hospital, 1955, Cleveland, Ohio
20. National Institutes of Health, Department of Health, Education and Welfare, 1954, Bethesda, Maryland
21. University of Nebraska, 1954, Lincoln, Nebraska
22. New York University, 1949, New York, New York
23. Northwestern University, 1942, Chicago, Illinois
24. Northwestern University, 1963, Chicago, Illinois
25. Ohio State University, 1954, Columbus, Ohio
26. University of Oregon, 1949, Portland, Oregon
27. Oxford University, 1954, Oxford, England
28. University of Pennsylvania, T. W. Evans Museum, 1949, Philadelphia, Pennsylvania
29. University of Pennsylvania, 1964, Bryn Mawr, Pennsylvania
30. University of Pittsburgh, 1963, Pittsburgh, Pennsylvania
31. Seton Hall University, 1958, Orange, New Jersey
32. University of Southern California, 1950, Los Angeles, California
33. University of Tennessee, 1954, Memphis, Tennessee
34. University of Texas, 1955, Houston, Texas
35. University of Toronto, 1950, Toronto, Ontario, Canada
36. University of Washington, 1949, Seattle, Washington
37. Washington University, 1949, St. Louis, Missouri
38. West Virginia University, 1960, Morgantown, West Virginia

Individuals

1. Dr. J. William Adams, 1954, Indianapolis, Indiana
2. Dr. Arthur Lewis, 1949, Dayton, Ohio
3. Dr. Phelps J. Murphey, 1954, Dallas, Texas
4. Dr. Morse R. Newcomb, 1950, Shaker Heights, Ohio
5. Drs. Frederick and Harold Noyes, 1939, Chicago, Illinois
6. Dr. William M. Thompson, 1954, Pittsburgh, Pennsylvania

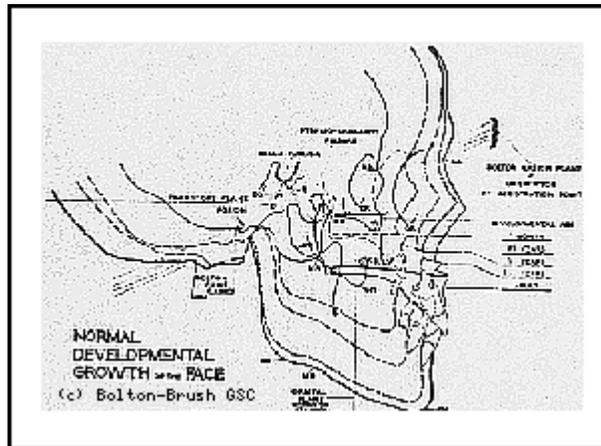


Figure 6

Charles Brush dies June 15, 1929 at the age of eighty. His will provided for the study of race improvement and the rationale for world-wide population limitation. A grant-in-aid for a period of five years was provided from his estate to extend the Western Reserve University Study into a comprehensive longitudinal study of the attributes of healthy growth.

Thus, with a continuation study established, the third annual health contest was extended over a six month period in 1929, and it took on special importance. Each school homeroom was asked to select a boy and a girl who best exemplified ideal health. Teachers and students also selected those who were judged as the scholastic and social best. In that summer, 104 finalists were examined and on the basis of some 900 factors, the winners were named.

More importantly, perhaps, this contest was also used to broaden the scope of previous examinations and evaluate a carefully structured set of research tests for the long term studies. Many notable Cleveland specialists and other Nationwide scientists aided Dr. Todd in preparing the record protocol used in 1929 and eventually in the longitudinal study. Tests were organized in five different areas (Table II).

The 1929 recruitment of subjects was also carefully planned in regard to preparing for a longitudinal study and consideration of the attributes of optimum growth rates and the conditions affecting them. Many more schools had become involved in the contests (Table III).

By the fall of 1929 all plans and forms had been finalized, and Drs. Todd and Broadbent were actively recruiting participants for the longitudinal study about to begin.

1930-1938

This period was marked by intense activity by both the Brush and Bolton Studies. Every three months in babyhood (0-1 year of age); every six months until 5 years and then every year through adolescence, children returned to the study.

TABLE II **TESTS**

1. Physical
 - list of body measures (25)
 - radiographs of 6 skeletal areas (hand, elbow, shoulder, hip, knee and foot)
2. Mental
 - psychological tests
 - behavioral tests
3. Functional Health Inquiry
 - family physician reports
 - hand-eye coordination tests
 - psychomotor development
 - food preference inquiry
 - strength of muscle test
 - foot prints in weight bearing and sitting
4. Genetic and Environmental Antecedents
 - questionnaire about personal and family education,
 - health status,
 - familial illnesses tendencies,
 - occupation
 - recreation
5. Dentofacial
 - photographs
 - tooth and mouth conditions
 - unique radiographs of jaw alignment
 - tooth impressions

TABLE III
SCHOOLS INVOLVED IN THE STUDIES

Public Schools

- Cleveland
- East Cleveland
- Cleveland Heights
- Shaker Heights
- Lakewood
- Euclid

Private Schools

- Western Reserve Academy
- University School
- Hawken School
- Hathaway Brown
- Laurel School
- Park School

Nursery Schools

- School of Education
- Western Reserve Nursery School
- Day Nursery Association

for sometimes two full days of testing during which they shuffled about in paper slippers, were measured, x-rayed, put blocks in holes, were tested for steadiness of hand, drew pictures, took tests, etc.

At one time Dr. Todd had some 50 assistants making relevant observations and tests at every visit. In spite of the ever increasing activity, all tests were performed in a way as to provide comfort, instill confidence and provide for a sense of security for the children. Most children looked forward with enthusiasm to the next visit.

Also during this time new participants were continually recruited into the study, or rather were invited. At various times babies were selected, at other times adolescents, and some adults. All were studied consecutively (serially) for varying numbers of years (Figures 7-11).

Dear Mr. and Mrs.

Would you be interested in having your child undergo a physical examination by the Brush Foundation at regular time intervals for several years? Our research division is making a study of the physical and mental development of young children and we are particularly anxious to carry on an intensive study of three hundred selected children over a period of years. The plan of this study involves the examination of:

1. Children under one year of age every three months.
2. Children between one year and five years of age every six months.
3. Children over five years of age once a year.

We believe that your child is in the _____ age group. If you decide to join us in this endeavor it is essential that you do your part by keeping a record which would involve about a half hour's work each week. We will, of course, explain this in greater detail at your first visit. The record thus made will form an exhaustive story of your child's development and will be your property as soon as copies can be made.

It is customary for us to furnish the parents and the child's physician a report after each examination. We are glad to consult the latter concerning the child's record. We give advice concerning the well-being of the children we examine, point out the need for professional attention when such is indicated by our X-ray findings and physical examinations. We do not give professional medical advice but refer all such matters to the physician in charge of the child.

Please signify your interest in participating in this research by filling out and returning the enclosed form to us.

(c) Bolton-Brush GSC

Very truly yours,

Figure 7

Brush Foundation Study of Growth and Development

I wish to enroll my child in this study of growth and development.

Name _____

Address _____

Telephone number _____

Name of Child _____ Birthdate _____

Father's Name _____ Age _____

Mother's Name _____ Age _____

Name of child's physician _____

Address _____

Do you consider that you are permanent residents of greater Cleveland?

Are you reasonably certain that your child will not be away from Cleveland for long periods of time during the next four years? _____

Can you be reasonably certain of having your child in our offices within four days after notice? _____

Data concerning other children

<u>Name</u>	<u>Birthdate</u>	<u>Birthplace</u>	<u>Sex</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Do you desire to enroll your older children if they fall within one of our age groups? _____

Do you wish to consult with a member of our staff before making a final decision? _____

(C) Bolton-Brush GSC

Figure 8

Figure 9

Dear

In reply to your inquiry the serial health examination of the Brush Inquiry is a study of the well child with a view to registering his health reserves.

The examination consists of determinations of

1. Physical growth by measurement.
2. Physical development by X-ray.
3. Neuro-muscular development by tests of muscular strength, control and coordination.
4. Mechanical ability and mental progress.

In addition, by cooperation with the Bolton Study, an investigation of the growing face, teeth and respiratory passages is made on each child.

The examination lasts about two hours and its actual cost to the Foundation is \$50.00.

The Board of Admissions reviews each application. If the child can be fitted into the research program, the parents pay the sum of \$25.00 per year toward the cost of examination. This sum is set as an annual subscription so that examinations can be made at whatever interval the ascertained progress of the child may indicate, without further cost to the parents.

If the parents of a child handicapped by disability or

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Figure 10

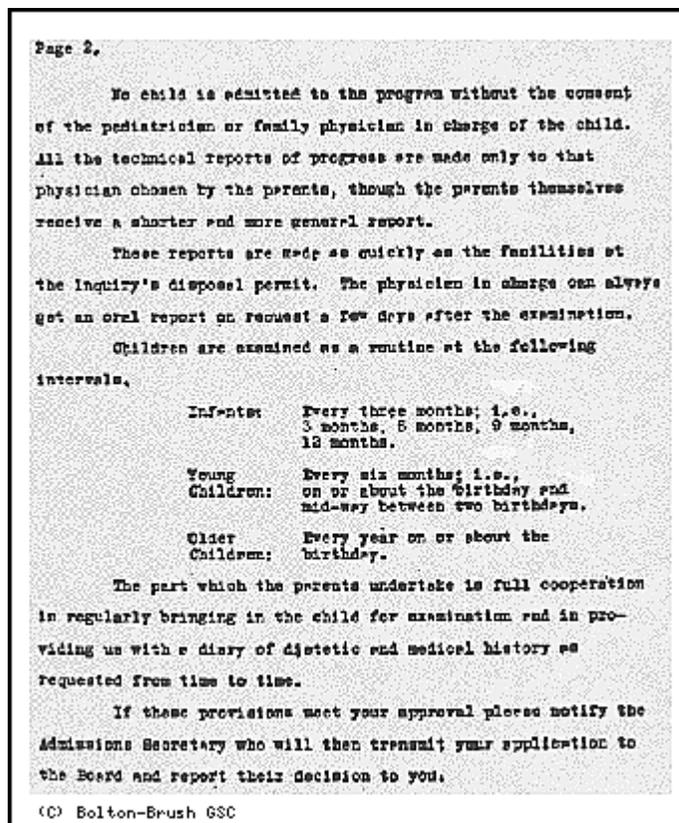


Figure 11

The participants have often been characterized as selected from the privileged, rich, upper class, and families where the husband held a professional or upper managerial position. The heritage of these children has also been characterized as American-born children of Anglo-Saxon or Teutonic origins, children of Sicilian immigrants or black children. This, however, is not entirely accurate. It is an outsider's average view and, to the extent it is true is more likely incidental and not an intent. The best normal people ("well born") were selected, not the richest by any means. Dr. Todd had only a few requirements (Figure 12), which in those days, in essence, amounted to a recommendation for participation by the family physician and parents. However, acceptance was not viewed lightly; being identified as a well-born, healthy child and being included in this famous Cleveland study was considered an honor and a mark of distinction and good health. Parents also felt that inclusion in the study might directly benefit their child, because the study gave recommendations, and made referrals should a problem be noted (preventive medicine!). They also felt that they were participating in valuable research which would benefit generations to come (Figure 13). (Indeed the selection factors may be fortuitous in terms of applying the findings to present day children.)

Participation in the Research Studies of the Brush Inquiry requires:

1. Approval of the family physician, or the special physician taking care of the child.
2. X-rays at stated intervals. In the study of adolescence these are to occur once a year on or near the birthday.
3. Psychological examinations on or near birthday.
4. Complete cooperation of the parents in providing all information and records concerning the child required by the Inquiry. This will include current records on the health and behaviour of the child.
5. A permanent residence in Cleveland or its vicinity.
6. Responsibility of parents to see that the child arrives at the place of examination promptly at the time set on the appointment date.

1. A report of the Inquiry of findings and results of each examination will be sent to the designated physician as soon after the examination as available data can be collected.

2. The Inquiry guarantees the strict privacy of all records.

(c) Bolton-Brush GSC

Figure 12

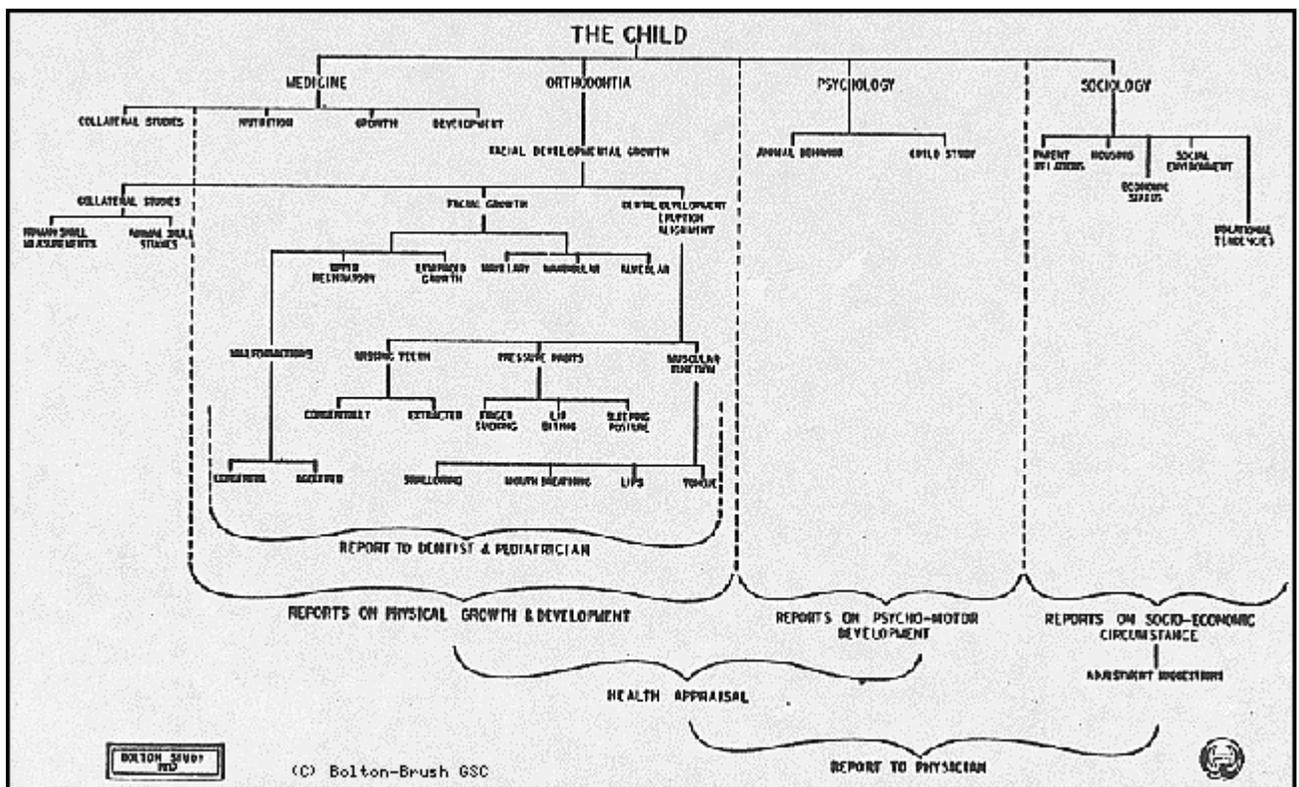


Figure 13

The x-ray studies were considered an invaluable tool in establishing permanent records of the child's growth and development. Because bones are acutely sensitive for reflecting other body conditions,

they provide permanent records with regard to effects on the growth process of race, sex, age, maturity and the history of ailments, accidents, stress, strain and other shortcomings of health. For many years thousands of x-rays were taken by Mrs. W. Kuenzel and her assistants as indicators or milestones of biological process (Figure 14). (Dr. Todd called Mrs. Kuenzel an expert and a genius. Today a healthy recall participant at 82 years of age, she recalled much of the present information for the present historical review.)

Some previous ideas of maturity (simply to be tall and thin was thought to be well developed and mature; just to be short and fat was regarded as poorly developed and immature) were clarified and expanded considerably. Skeletal maturation as another key measure of physical health, less subject to fluctuations than merely height and weight, was soon noted to be a most reliable source of indication of maturity of the individual child.

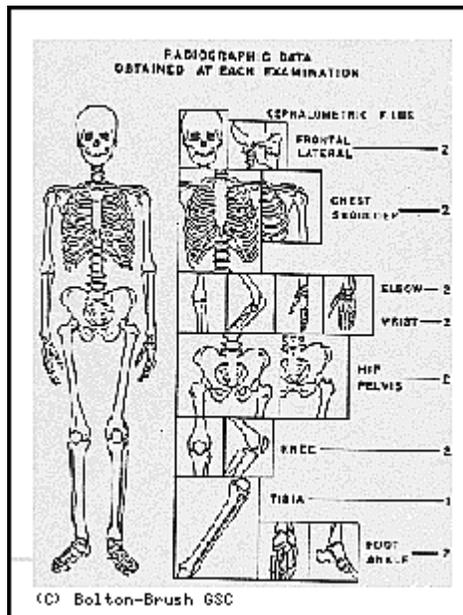


Figure 14

The roentgenographic cephalometric technique received special distinction throughout the years. Remembered by participants as the "ear torture machine" this apparatus and the findings it yielded became very important to the orthodontist and other health disciplines (Figures 15-17). It was clear that the face quickly reflected the health of the patient, and that many diseases of childhood influence the growth patterns of the head and face. This understanding gleaned from cephalometric research came to exemplify the basic intent of the studies and their application.

The animated motion picture "Normal Dentofacial Growth" developed by the Bolton Study with the active participation of Charles Bingham Bolton, provided a graphic representation of the changes that occur during childhood. The importance of these achievements, exemplified as "cephalometrics," has become realized, and they have become adopted by the orthodontic profession as standard practice and are taught in all orthodontic training programs. Also an integral part of teaching, the subject facial growth and development reflects largely the foundations laid by "cephalometric." In view, cephalometrics represents the greatest single advance in the science and practice of orthodontics (Tanner, 1981).

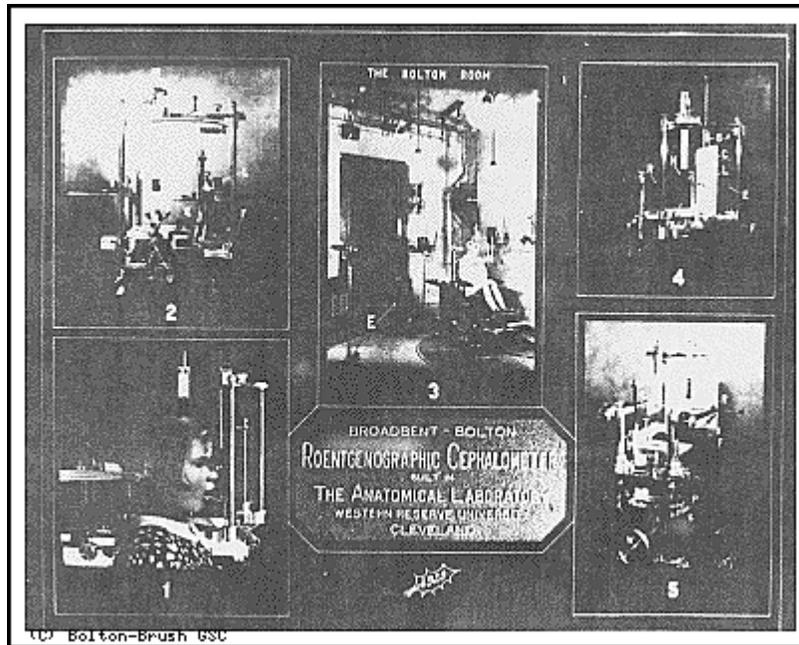


Figure 15

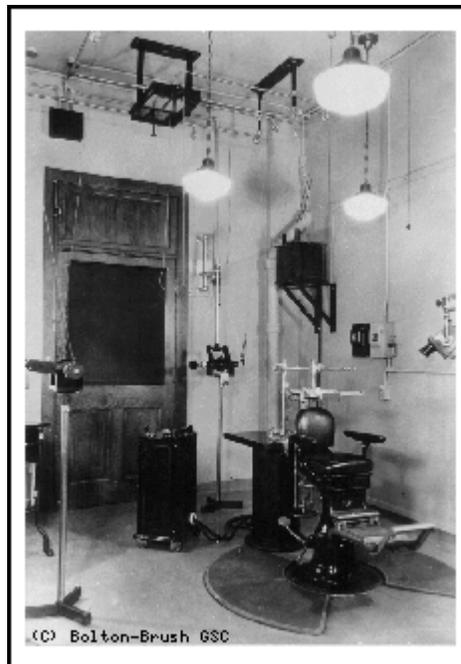


Figure 16

Figure 17

A full inventory of psychological testing is also performed. Forty different mental, skill, aptitude and personality tests were conducted. Home behavior, sleep behavior and other traits assessed (the yearly questionnaire had 588 entries). Many standard tests commonly used in psychology to assess "abnormal" had to be discarded when the study began because these tests were not applicable to "normal" children. Rorschach ink-blot tests were revised.

Some interesting results were noted in the "brain wave" tests. All previous work in this area was based on abnormal or brain-injured children. It had been previously published elsewhere that a "problem brain wave" indicated a problem child. This was totally discredited by the study as this "problem brain wave" was seen time and time again in happy, balanced children who presented no problem at all.

1938

Dr. T. Wingate Todd died in December of a heart attack. His life-long work was widely acclaimed. In 26 fruitful years he had introduced many innovative methods in the teaching of anatomy, developed vast collections of human and primate skeletal material, established an astonishing Departmental Library, as editor of *Child Development*, was a member of the White House Conference, and was elected a Fellow of the Royal College of Surgeons. At his death many study participants wrote the lab urging continuation of his work, and more funds were extended from the Rockefeller Foundation to this end.

1939

Realizing the demanding positions Todd had held, Dr. Norman Hoerr was named as Todd's successor for the Chair of Anatomy, and Dr. William Walter Greulich became the second Director of the Brush Inquiry in the Department of Anatomy. Dr. Greulich's appointment would later result in one of the Brush Inquiry's main achievements; that of the timing of human ovulation by means of body temperature fluctuations. This is still used to supplement other, newer methods for either achieving or avoiding pregnancy. Dr. Broadbent continued as Director of the Bolton Study in addition to his extensive private practice of orthodontics.

1939-1942

During this period the examinations continued and new enrollees were accepted. However, due to the mounting pressures of war, the program began to reduce in scope and magnitude. The mental and physical tests were at first shortened, then discontinued, and finally summarized for publication. Also, in 1942, because of the lack of x-ray film and technical help, films of the hand, elbow, shoulder, hip, knee and foot were discontinued as a full series. Recordings for height, weight and x-rays of the hands were transferred to the Bolton Study. By the end of 1942, it was decided that active testing for the Brush Study would cease. It had become, however, the largest, longest-term, most extensive study on children and adults yet accomplished (Figure 18). Two hundred and fifty thousand x-rays had been taken, 22,000 physical examinations, 90,000 mental and psychological tests had been made, all on some 4,000 children (Figure 19). Emphasis would now be given to the compiling and publication of results.

1944

Dr. William Greulich was elected Professor of Anatomy in the School of Medicine and Stanford University, but continued as Director of the Brush Foundation until 1950.

In accordance with the original plan, the Brush Foundation study of the growth and development of normal children will be completed on June 30 of this year. Next year will be devoted to working up and preparing for publication the vast amount of data which has been collected during the period of study. These publications will make available to physicians, parents, and all others interested in children a summary of what has been learned about human growth and development in this, the most comprehensive investigation of its kind that has ever been undertaken. It is gratifying to me to be able to announce that this important study of child development made by the late Dr. T. Wingate Todd has been successfully completed, and that we believe that the assessment of the work will establish a signal advance in existing knowledge in this field.

Our study has been aided by substantial grants from the General Education Board of the Rockefeller Foundation, the Cleveland Foundation, and other co-operating agencies. In a very real sense, however, it was made possible only by the generous cooperation of the participating children and their parents. Let me thank you most sincerely for what you personally have done to make this project a success.

For the duration of the war, the major activity of the Brush Foundation will be its chemical and endocrine studies pertaining to the war effort which were undertaken recently at the request of the National Research Council. Its maternal health program, its investigation of the causes of sterility, and its study of the sociological and biological implications of feeble-mindedness will also be continued. In these as well as in its future activities, I trust that the Brush Foundation will have your continued interest and support.

Yours very truly,

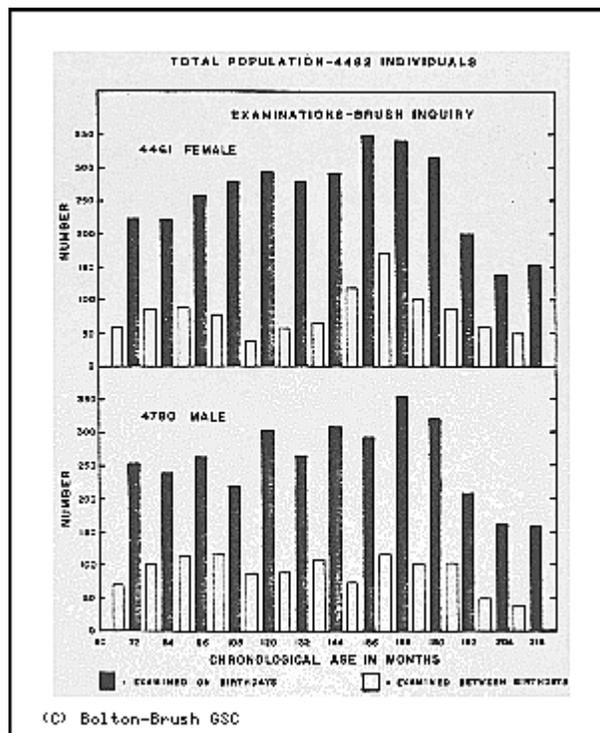
W. W. Greulich,
Director, The Brush Foundation.

WVG:MD

P.S. The Bolton Study of the development of the face and eruption of the teeth, which is under the direction of Dr. B. Holly Broadbent, will be continued, thus making available to the participants further progress reports on dento-facial development.

(C) Bolton-Brush GSC

Figure 18



(C) Bolton-Brush GSC

Figure 19

1946

Dr. Idell Pyle, who had been associated with the Study since 1940, was asked by Dr. Hoerr to complete her doctoral credits under him by compiling films for an atlas. This was subsequently accomplished, as were four other atlases of normal growth of various body regions. Dr. Pyle continued her lifelong dedication to the study of human skeletal maturation until retirement, for health reasons, in 1981.

1948

Realizing the enormous value of the work being produced, the Bolton Study was incorporated as a department of the School of Dentistry, Case Western Reserve University. A curriculum was organized to teach normal craniofacial growth to dental students.

1952

In 1952, another event occurred which was to have considerable impact on the Bolton Study. This was the addition of Dr. B. Holly Broadbent, Jr. as a research and teaching associate. He had graduated from Western Reserve University Dental School, studied orthodontics under his father's guidance, and then began conducting a busy orthodontic practice with his father; like the father, the son was deeply interested in the study of facial growth.

1959

In 1959, it was decided that the Bolton Study would be terminated and active enrollment ceased. More time was now to be spent studying and collating the vast pool of information collected. Since the study recruited subjects for some 30 years, with ongoing studies continuing for many years on the original children, the ages obtained now included many young adults. The number of subjects included approached 6,000. Forty to fifty thousand plaster casts of children's teeth were gathered from the period of the deciduous dentition through the eruption of third molars, some 409,000 x-rays were on record for study, an average of 15 films were taken per participant, 600-2,000 x-rays were available per age (average of 1,170), 3 pure longitudinal cohorts existed, etc., (Figure 20).

1967

In 1967, Dr. Broadbent, Sr. suffered a stroke, which eventually necessitated his retirement in 1969. To ensure that his work was carried on, Dr. B. Holly Broadbent, Jr. was named Director of the Bolton Study.

1970

In 1970, under the direction of Mr. Charles Bolton, Dr. David Weir (Chairman of the Board of Managers of the Brush Foundation), Dr. B. Holly Broadbent, Sr. and Dr. B. Holly Broadbent, Jr., it was decided that the Brush Inquiry records still housed in the School of Medicine could be best utilized in research and teaching by combining all materials in one center to be call the Bolton-Brush Growth

Study Center. This was to be located in the new Bolton Dental Building of Case Western Reserve University (Figures 21-22), where the Center is located today.

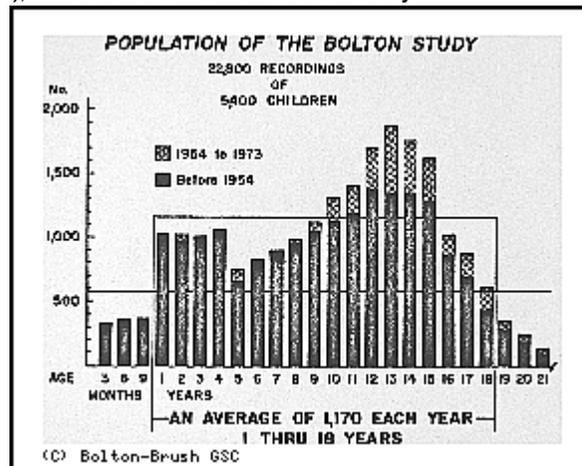


Figure 20

1973-1975

This was a landmark period when the "Bolton Standards" were first presented at the Third International Orthodontic Congress in London (1973). The Standards were then methodically and meticulously prepared and published in 1975 (Figure 23). This provided clinicians and researchers with an invaluable tool for understanding and assessing the growth of the craniofacial complex.

Mr. William Golden, a research associate with the Bolton Study from 1945 to 1981, was a co-author of the Standards. He contributed his unique artistic and technical abilities to both the research and the teaching activities of the Center.

THE BOLTON-BRUSH GROWTH STUDY CENTER
SCHOOL OF DENTISTRY, C.W.R.U.

AN ASSOCIATION BETWEEN THE BOLTON STUDY AND THE BRUSH INQUIRY

Submitted by: Mr. C. E. Bolton, Dr. D. E. Weir, Dr. B. H. Broadbent, Sr. and
Dr. B. H. Broadbent, Jr.

To: Dean David Scott, C.W.R.U. School of Dentistry and President Robert Morse, C.W.R.U.

Background

Since their origin in the late 1920's, the Brush Inquiry and the Bolton Fund have been a functional part of the teaching and research programs of the C.W.R.U. School of Medicine. Although each has maintained its autonomy and carried on investigations of the same children and youths through independent financial support, there has been a direct association between them, with the Department of Anatomy, and also the School of Dentistry.

The Bolton Study has directed its interests primarily to the investigation of dental-facial developmental growth and cephalometric techniques, while continuing to take records of many returning patients who were in the Brush Inquiry. The Brush records of human development, since the cessation of active data collection in 1942, have been stored intact with their primary use in the development of skeletal x-ray standards by Drs. William Walter Greulich, the late Norrand L. Hoerr, S. Idell Pyle, and their associates.

Since 1965, Dr. Pyle, in addition to other activities, has been engaged in the training and advising of medical students in the reading of wrist x-rays under the auspices of the Division of Health, Education, and Welfare for determination of skeletal maturation for the National Health Examination Survey of a representative sample of children and youths from forty areas of the United States.

An Association for Productive Use of the Collected Data

With the physical move of the Bolton Study to its new quarters in the School of Dentistry, and because of the close correlation of the records and individuals in the Bolton Study with the Brush Inquiry, it was deemed practical and agreed upon by both groups to officially associate by establishing the Bolton-Brush Growth Study Center. Potential areas of co-operation in this association lie in:

- A. The joint records offering unlimited possibilities for research and investigation into the areas of human developmental growth both for interested individuals of C.W.R.U. and also those from other areas in the country including the National Institutes of Health.
- B. The continuation of the collection of long-term records to further expand the research information available (second and third generations, etc.); and, more importantly, to re-assess individuals with original records.

(C) Bolton-Brush GSC

Figure 21

- C. The training of medical and dental personnel in the area of roentgen interpretation and clinical utilization. The routine use of wrist X-rays and skeletal-maturation information by the orthodontic students has been limited in the past, but offers a fine opportunity for correlation of skeletal age with dentofacial development.
- D. The computerization of the information contained in the studies for exchange with other growth centers could be workable and very advantageous.

Future Relationship

The Bolton Study and the Brush Foundation will remain autonomous with their respective Boards of Trustees and Managers continuing as before. The "Bolton-Brush Growth Study Center" will be a distinct entity under the functional structure of the School of Dentistry. Within the University structure, appointment of the Director of the Center and the Advisory Committee will be the responsibility of the Dean of the School of Dentistry upon recommendations from the Bolton and Brush Boards. Upon formal recognition of the Growth Study Center by the University, the Advisory Committee, as suggested on the attached organizational chart, will be developed. The Committee members will be selected on the basis of their willingness and ability to lend guidance in the areas of research projects.

Waiting researchers will have their names submitted to the Dean by the Director of the Study for formal recognition as University affiliates. Their designation will be determined by the individual circumstances; such as, "Research Associate, Research Fellow," etc.

The financial responsibility of both the Bolton Study and the Brush Foundation will continue independently except in the area of a possible agreed sharing of remuneration to an appointed "Research Supervisor" of the Brush records and other future "joint ventures." No firm financial commitments are to be made at this time; and there will be no financial responsibility on the part of the University except regarding physical space.

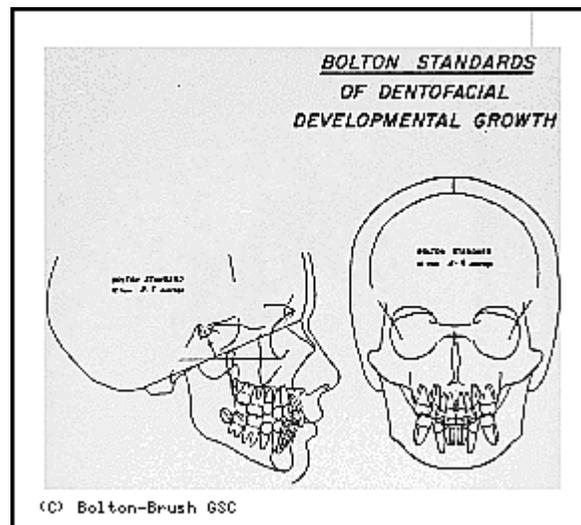
Under a current verbal agreement with Dean Scott of the School of Dentistry, the physical area of the Bolton Study (the west end of the third floor of the Bolton Dental Building) will be available rent, utilities, and maintenance free, for an undetermined length of time. In this space, the Brush records will continue to be housed, and a location for the prime Research Supervisor supplied. General working area for students and researchers will be available as agreed by the joint Directors of the Bolton-Brush Growth Study Center. The Bolton Study will maintain the basic responsibility for the physical space utilization.

Formal Action

Since it is desirable to have the Bolton-Brush Growth Study Center a recognized entity within the University, both from the standpoint of inter-faculty appointments and formal relationships with outside investigators, the Trustees of the Bolton Study and the Board of Managers of the Brush Foundation are pleased to accept formal recognition of the Center as an integral part of the School of Dentistry of Case Western Reserve University.

(C) Bolton-Brush GSC

Figure 22



(C) Bolton-Brush GSC

Figure 23

work of the Bolton investigations over the years.

1977

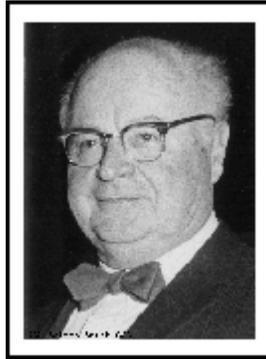


Figure 24

In this year Dr. Broadbent, Sr. passed away. Suffice it to say, that Broadbent cephalograms are still a prime instrument in diagnosing and treating disorders of facial growth, just as are Todd's skeletal maturation atlases used in diagnosing and treating children with more general growth disorders. Broadbent's accomplishments were many as a dedicated scholar and Professor of Dentofacial Anatomy since 1929 (Figure 24), but he will probably be most remembered for the cephalometric procedure designed to uncover fundamental aspects of facial growth (Figure 25). Perhaps his own words say it best:

"The Bolton Study began at the old Medical School, in the original 9th and St. Clair Department of Anatomy quarters. No office, no secretary, no technicians, no filing cabinets. Just the idea, determination, and willingness to give of my time and effort."

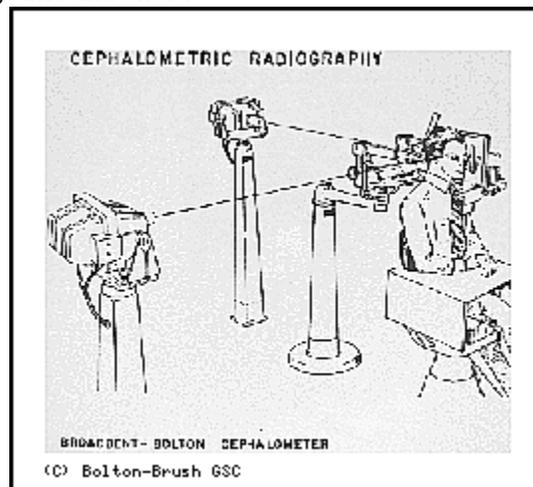


Figure 25

Also in this year, a long-term recall project was begun under the leadership of Dr. B. Holly Broadbent, Jr., Dr. David Weir, Dr. Greulich and Dr. Pyle. It was designed to recall the "Bolton Faces" (balanced faces) and a group of individuals, who had previously been studied extensively as babies and young children. The recall goal was to assess their present health status. This sizable study continues today.

In this year after the death of the Honorable Frances Payne Bolton (Figure 4), after many, many years of personal and financial support, such assistance ceased. The study of Growth and Development lost an invaluable benefactor.

1982

In 1982, from the original populations of the Bolton and Brush Studies, some 700 of the original 6000 participants were selected for recall in a study conducted by Dr. Rolf Behrents, Dr. B. Holly Broadbent, Jr. and Dr. Donald H. Enlow. This was done in order to assess their present general health, dental health, and determine if any craniofacial alterations had occurred during adulthood.

In all, some 113 participants were located and returned for further examinations. Results of the examination revealed mortality and morbidity rates were low for this group (age range: 36-83) as they were generally in good health. Data indicated further that participants had generally gained weight and some participants had gained in stature since young adulthood. The dental health of the individuals was good with a low rate of tooth loss and few temporomandibular joint problems. Cephalometric examinations surprisingly revealed a continuing growth of the craniofacial complex throughout all adult age spans.

This recall study is continuing as there are many implications for medicine and dentistry involved in a craniofacial complex which changes through time.

Summary – A Beginning

Much is left out in a brief historical review such as this. Over the years, many students of child maturation and dentofacial development have utilized the records, and a multitude of excellent research publications has emerged. Space does not permit a full account of the monographs, papers and books which have been based on this records, but there are literally hundreds.

It is also evident that this wealth of data continues to be invaluable and one-of-a-kind resource, and these stored records continue to be vital growth records whose appreciation is not unique to a single generation. The work accomplished with meticulous perfection will not likely ever be undertaken again, and it will provide insight into the continuum of growth and development of individuals for generations to come. With these materials, we can continue to clarify and understand the marvels of the laws governing growth and development and provide for new vistas in medicine and dentistry.

Today, there are continued extensions of Todd's and Broadbent's work as the Bolton-Brush Growth Study Center, under the watchful eye of Dr. B. Holly Broadbent, Jr., continues to carry on research in developmental growth according to some of its original goals. The ultimate and continuing goal of the Study is the compilation of standards of developmental growth that may be used as frames of reference for the assessment of the myriad changes that take place in the growth processes of the human body.

Regarding the participants presently being recalled, now adult, it is clear they still remain enthusiastic and optimistic. Many ask "why did it take so long to call us back?". They are very interested in the results of the research, and are continually giving, in terms of adding to knowledge by participating in this valuable undertaking, as it may benefit others. They remain in good health, which was what brought them to the original study years ago, is a mark of distinction which remains. It was an honor to be included in the study; faith in the future has drawn them back, for they still feel the honor, the caring of the investigators, and progress for humanity is apparently their goal. They were and still are indeed distinctive in health, and they remain special indeed. Thus, this history is dedicated to the participants in the studies.

THIS HISTORY IS EXCERPTED FROM THE FOLLOWING SOURCES:

Atlas of Skeletal Maturation, by T. Wingate Todd, C.V. Mosby, 1937.

Life in Our Hands, the Story of the Brush Foundation, by Theodore Hall, the Brush Foundation, 1946.

"Frances Payne Bolton Honored," editorial reprinted in the American Journal of Orthodontics, May, 1959.

A Radiographic Standard of Reference for the Growing Knee, by S. Idell Pyle, Charles C. Thomas, 1969.

Bolton Standards of Dentofacial Developmental Growth, by B. Holly Broadbent Sr., B. Holly Broadbent, Jr. and William H. Golden, C. V. Mosby, 1975.

The Brush Foundation, by David R. Weir (editor), The Brush Foundation, 1980.

"Dr. Todd's Bones: The Macabrae Collection that is Making Scientific History Here," by Mark Gottlieb, Northern Ohio Live, 1982.