Research Methods in Orthodontia*

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In instituting a piece of research one must have a definite idea of what is to be done, a definite purpose, and a definite plan of attack. Many people believe that research consists in gathering all-inclusive records and making certain observations and letting it go at that. I am reminded of a visit I had with Dr. Ales Hrdlicka a few years ago when I went to consult him about using certain landmarks in measuring dental arch growth. He mentioned the fact that too often people become ambitious and begin to gather records with no definite purpose in mind. "Look," he said, "these drawers are full of records from all corners of the earth, but for the most part they are worthless. Everyone wants to do research, but most of them waste time and effort." Research means more than making observations and recording measurements.

Now, then, what about methods of research in orthodontia? Do they differ from methods in other scientific fields? How does one go about starting a scientific investigation in this field?

First, let us consider how we are to develop a definite idea of what is to be done in a problem calling for solution. Of primary importance is a thorough knowledge of the literature. But that means more than knowing what has been written. The student must adopt an attitude of friendly hostility towards what he reads. He must make a critical analysis, not only of the conclusions reached but also of the manner of handling the data. Through such a critical analysis he learns what the problems in the field are. Some new problem may present itself, or he may see the need of verifying the work of someone else. For the student who wishes to learn to appraise the literature, to separate the chaff from the wheat, the seminar offers a valuable discipline. This is as true in orthodontia as in other fields. All scientific problems are concerned with the relation between phenomena, and methodology is the same, whether the field is growth and development, astronomy, physics, chemistry, psychology, or orthodontia.

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Equipped with a definite idea, the investigator should have a definite purpose in making the study. To illustrate, I should like to tell you how I happened to start the investigation in progress at the Merrill-Palmer School in Detroit.

When I was a student at the Angle School I was taught what normal occlusion of the teeth is in the deciduous and early adult dentures. I was also taught that the problems of orthodontia are concerned with the growth and development of the masticatory apparatus. I was not taught what constituted normal occlusion during the stages of development intervening between the completion of the deciduous denture and the reaching of the early adult stage. So I conceived the idea that what I needed to learn was what happened to the teeth and dental arches from the time the deciduous teeth were completed to the time when the early adult dentition was completed. I made a thorough survey of the literature, only to find that nothing had been published on the subject. I had previously talked to Dr. Lloyd Lourie, who planned to observe some children who had appeared for orthodontic treatment. I had also seen some cases that Johnson and Hatfield had observed over a period of a year or two. These two plans helped to sow the seed of my idea, but where these men were interested in determining whether or not cases needed treatment, I wanted to find out something about growth changes from early childhood to adolescence. Were there well-defined phenomena occurring in normal development, quite certainly outside the realm of abnormal development, or were there many variations in these phenomena which made it difficult to determine just what constituted normal or abnormal development at this time? I had a definite idea, and my purpose was to find out, if possible, what these various manifestations of growth were, and to see if I could classify certain ones as normal, abnormal, or borderline.

Now we may consider the plan of attack. In orthodontia, as in the general field of growth and development, three methods of procedure are possible.

One procedure is to observe and measure a large number of individuals of different ages in order to gain a general idea of the course of growth and development. This is the plan followed by Milo Hellman in his investigation of the changes in the face influenced by the teeth. The material available to him was a large number of Indian skulls of various ages. Since he did not know their exact chronological ages, he divided them into groups representing various stages of development. He was justified in such a grouping because he knew that all persons reach the same stage of development at some time, but not at the same age. He then made various measurements, determined the averages and standard deviations of the growth curve and, on the basis of these figures, was able to say what the general course of the height growth of the face had been and what rôle the teeth played in it. He made a real contribution to the science of dentistry which will lead to other studies in this field.

However, one must realize that such a procedure, based on observation of a large group of individuals at one stage of development, whether the material is live persons or dry skulls, shows only general trends. For example, the measurement of a large number of children showed that there was an acceleration of body growth at puberty. Later, more advanced methods showed that this acceleration was much more sudden than the earlier investigation had led us to believe. However, the possibilties of this method are by no means exhausted, and its further use will yield much valuable information in our own and other fields.

Clinical observation is another method of approach to our problems. The clinician, having in mind a picture of the normal, observes the cases that come to him and arrives at certain conclusions about malocclusion of the teeth. His observations are likely to be less systematic and complete than those of the laboratory worker, though his methods have undergone many refinements during the last decade. However, the importance of the information gained in clinics must not be underestimated, for it is here that much of the new information in this field will be directly applied. That is why so many of Dr. Angle's contributions to the science of orthodontia have been valuable. Though his attention was focussed on the various manifestations of abnormal development of the teeth and jaws, he always had in his mind's eye a picture of what constituted normal growth and development. He was the master observer.

In recent years another way of approaching problems of growth and development has been recognized. This method follows an individual over a long period of time, making systematic measurements and observations at regular intervals. This was the method I adopted in 1923 when I began an investigation of the growth changes of the teeth, dental arches, and occlusion at the Merrill-Palmer School. While attending the White House Conference on Child Health and Protection in 1930, I was pleased to learn that they had formulated the following conclusion, after much investigation and deliberation: "The careful study of a relatively small number of individuals, continued over a period of years, seems to be the most promising method of attack upon the majority of unanswered questions in the field of growth and development."

Once I had adopted this plan of procedure, it was necessary to have a specific plan for gathering the necessary records. It seemed to me that if I was to learn something about the changes occurring during the growth and development of the teeth and dental arches, especially during late childhood and preadolescence, I should have to obtain material evidence that could be looked at forwards and backwards and at any time. What would be better than to obtain impressions of the teeth and dental arches once a year from the time deciduous teeth were all erupted to the time when the early adult denture was completed? Such a series of models, with the observations and measurements accompanying them, would supply me with evidence obtained under known conditions and acceptable for checking and rechecking. I should have a running record of events which could be studied from various angles, and a relatively large number of these series of models would give us records unequalled in other fields of biological research. We should not only have recorded measurements, but should be able actually to see the changes occurring in the growing dental arch. Individual variations, which seemed to me more important than general trends, could be observed and recorded. It was just such a study that had disclosed the pubertal spurt of growth to be much more sudden than the observation of general trends had shown.

Having this material available, I was next faced with the problem of how to deal with it. As soon as some of the series were sufficiently large to permit an observation of growth changes, it was necessary to select a method of studying the relations among the phenomena observed. This meant that some sort of standard must be formulated.

Here I followed the usual procedure, first making observations on the basis of experience gained in clinical practice, then testing these observations by statistical methods and, lastly, examining the results and drawing conclusions. In any scientific investigation one searches for the relation between pairs of variables. In our field there are a great number of variables. For example, the relation between the diameters of the deciduous and the permanent incisors; the relation between the spacing of the deciduous incisors and the alignment of the permanent incisors; the relation between intercanine growth and the alignment of the permanent incisors; the relation between the occlusion of the deciduous teeth and that of the permanent teeth; the relation between the Bogue Index and occlusion, etc., etc.

Let us make a few definitions so that we may follow the statistical phase of orthodontic research. Statistics has been defined as the science which deals with the frequency of occurence of different kinds or different attributes of things. Thus, if we are dealing with the incidence of measles, we are concerned with the frequency of occurrence of the disease in a given population in a given period of time. This frequency can be set down in the form of a simple curve or a column diagram.

Biometry has been defined as the science which studies the quantitative aspects of vital phenomena by means of precise and refined mathematical analysis of exact measurements. Many orthodontic problems lend themselves to biometric examination.

In searching for the relation between our two variables we make use of the scatter diagram, which not only shows graphically the presence or absence of relation between the two variables, but also enables one to judge by inspection the degree of relation or absence of it.

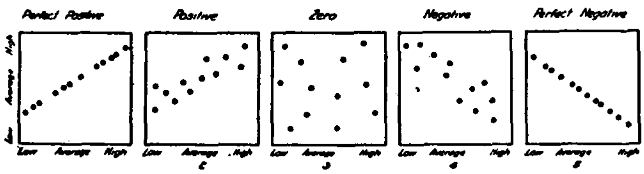

Figure 1

Positive and Negative Scatter Diagrams (Thurstone).

In Figure 1 there are five scatter diagrams illustrating the appearance of different degrees of relation between two variables. For our purpose I shall describe only the first three. In the first square we have a diagram showing a perfect positive relation between two variables; this might be the relation between the volume and weight of pieces of steel. Every member of the group studied is represented by a point in the scatter diagram. Every point tells two facts. The distance of the point from the horizontal base line of the chart tells one fact—the measurement of one of the variables. Its distance from the left vertical edge of the chart shows the measurement of the second variable. Thus we have the X variable indicated on the base line, from left to right, and the Y variable on the vertical axis, from bottom to top. One can see at a glance that the value of Y increases in strict proportion to increases in the value of X. We say that this relation is perfect and positive.

Now, let us take a hypothetical case in orthodontia. Suppose we are studying the relation between the diameters of the deciduous incisors and those of their permanent successors. If we have models of these cases before the eruption of the permanent incisors and afterwards, we can make accurate measurements of both the deciduous and permanent incisors and set these down on the scatter diagram. Suppose we find that the range in the diameters of the four lower deciduous incisors is from 11 mm. to 26 mm. and the range of their permanent successors is from 26 mm. to 36 mm. If in every case we found that the 16 mm. deciduous incisors were followed by permanent incisors measuring 26 mm., the 17 mm. incisors followed by permanent ones measuring 27 mm., and so on, there would be a perfect and positive relation between the two variables, and our scatter diagram would look like Figure 2.

But let us consider an actual study of the relation between these two factors. If we have recorded our measurements accurately and have records showing just what takes place when the permanent incisors have replaced the

DIAMETERS OF PERM. INCISORS

DIAMETERS OF DECID. INCISORS

MM	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	
26.0										𝍸	5
25.0									𝍸		5
24.0								𝍸			5
23.0							𝍸				5
22.0						𝍸					5
21.0					𝍸						5
20.0				𝍸							5
19.0			𝍸								5
18.0		𝍸									5
17.0	𝍸										5
	5	5	5	5	5	5	5	5	5	5	50

LOWERS

Figure 2
Scatter Diagram showing a hypothetical case in which there is a perfect positive relation, hence a correlation coefficient of plus 1.

deciduous ones, we can see at a glance the general relation between these two factors. I made such a prediction study in the paper entitled "A Quantitative Study of the Relation between Certain Factors in the Development of the Dental Arch and Occlusion of the Teeth."

Figure 3 illustrates what we found on making a statistical study of the problem. You will note that there is a scattering of figures on the diagram, but a rather strong tendency for them to hug the diagonal lines. Inspection showed a certain degree of relationship, and it seemed advisable to work out the coefficient of correlation. It proved to be +0.677, which is fairly high.

What do we mean by a correlation of +0.677? In modern statistical methods, the correlation coefficient is a pure number—that is, a constant which indicates the degree of relation between two variables. In this case the two variables were the combined diameters of the deciduous incisors and the combined diameters of their permanent successors. The coefficient of correlation varies from +1 to —1. When the relation is perfect and positive, as in the hypothetical case I described, the coefficient is +1. When it is perfect but inverse, the coefficient is —1. When there is no relation whatever between the two factors, the coefficient is 0. Other values indicate

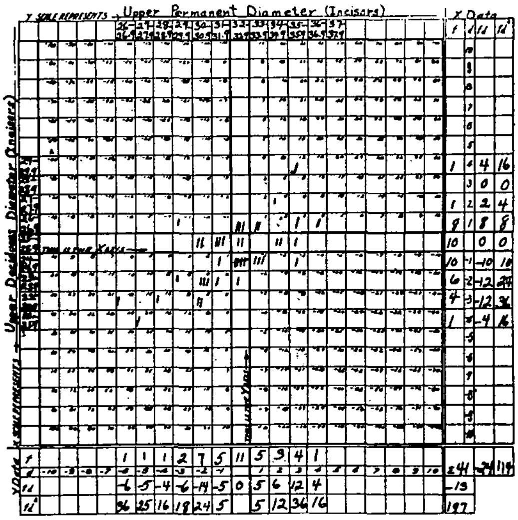

Figure 3
Scatter diagram showing relation between diameters of deciduous and permanent incisors.

intermediate degrees of relation. Thus, a coefficient of +0.8 indicates that the points on the scatter diagram cluster rather closely about a diagonal line across the diagram, whereas a coefficient of +0.322 indicates that they scatter more widely from the diagonal, but that a positive relation is still noticeable.

Thus the correlation coefficient is only a numerical way of describing the scatter diagram. However, though the coefficient is more concise, the diagram gives more information. The coefficient can be calculated from the diagram, but the diagram cannot be constructed on the basis of the coefficient.

To continue our illustration. How were we to interpret the correlation coefficient in this case? If the perfect relation was indicated by 1, then our figure of +0.677 showed that we could predict the size of the permanent incisors accurately in little more than 50 per cent of all cases. But unless we could say what the intercanine width must be to accommodate the permanent incisors in almost all cases, prediction was of no practical value.

UPPER DECIDUOUS INCISOR SPACING AND ALIGNMENT OF

UPPER PERMANENT INCISORS.

ALIGNMENT

SPACING DECIDUOUS INCISORS		WORST	WORSE		CONSTANT			BETTER		BEST	T.	T.
		1/3	1/2	2/3	1/1	2/2	3/3	2/1	3/2	3/1		
INCREASE 2 STAGE	0-3											16
	0-2			/							1	
	1-3											
	TOTAL	0	0	1	0	0	0	0	0	0		
INCREASE 1 STAGE	0-1						/	/			2	
	1-2	/	/		/	/		//	/		7	
	2-3		/	/	//	//					6	
	TOTAL	1	2	1	3	3	1	3	1	0		
CONSTANT	0-0	/	/								2	59
	1-1	//	/	/	//	/	///	//	/		13	
	2-2		//	///	/////	//	///	/	/	/	18	
	3-3	/	///	//	///// / /////	////	///	/	/		26	
	TOTAL	4	7	6	18	7	9	4	3	1		
DECREASE	1-0											
	2-0											
	3-2											
	TOTAL	0	0	0	0	0	0	0	0	0		
	TOTAL	5	9	8	21	10	10	7	4	1	75	75
	TOTAL	22			41			12				

Key

Spacing	0 = None 1 = Slight 2 = Medium 3 = Wide		Alignment	1 = Good 2 = Fair 3 = Poor

11979-3

Figure 4

Scatter diagram showing the relation of deciduous incisor spacing to alignment of the permanent incisors.

A calculation of the formula for prediction showed that our figure would fall within 1 mm. of the true value in 50 of 100 cases. Further analysis showed that the true value might be 4 mm. greater or less than the predicted value—a range almost equal to the entire distribution. Obviously, the relation between the two variables did not permit setting up a formula of prediction, in spite of a fairly high correlation. In this case observation and inspection of the measurements showed as much as statistical analysis.

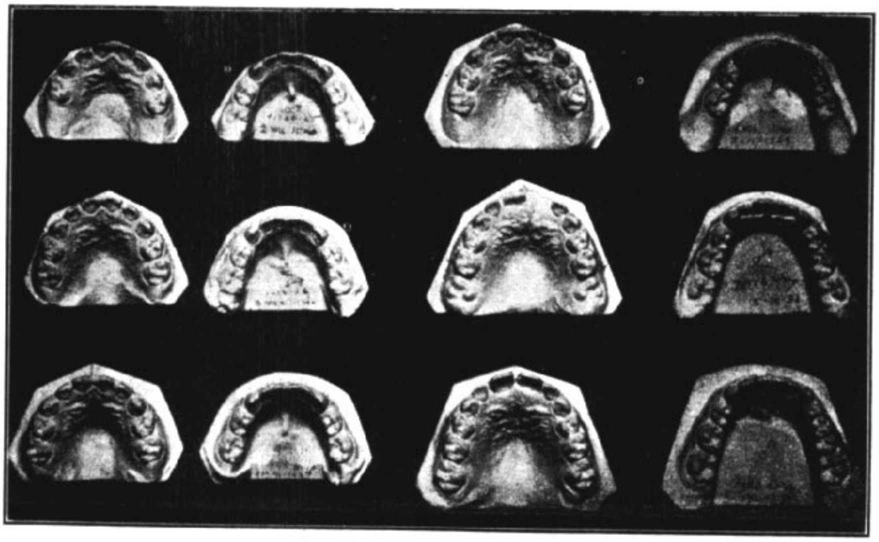

Figure 5
A series of models of the same case showing no deciduous incisor spacing and good alignment of the permanent incisors in the lower arch. Note the growth adjustments as the permanent incisors erupt.

Let us take another case in which calculation of the coefficient of correlation is unnecessary for practical purposes. Suppose we have several series of models showing the various stages from the time the deciduous incisors are in *situ* till the permanent incisors are in occlusion. We wanted to know what relation, if any, existed between the spacing of the deciduous incisors and the alignment of the permanent incisors. Figure 4 illustrates what we found. You will note that the diagram shows all possible combinations of spacing. Since there were no accepted standards of slight, medium, and wide spacing, we adopted our own, which we based on our experience in examining many cases. We also adopted a standard of alignment. Now, if an increase in spacing, especially from no spacing to wide spacing, is

INTER-CANINE GROWTH—DIFFERENCE IN DIAMETERS OF DECIDUOUS AND PERMANENT INCISORS— ALIGNMENT

MAXILLARY

GOOD ALIGNMENT

ICI	DID
2.0	5.0
2.5	6.5
3.5	7.0
4.0	7.0
4.0	8.5
4.0	8.5
4.5	5.5
4.5	6.5
5.0	8.0
7.0	7.5
Ave. 4.1	7.0

FAIR ALIGNMENT

ICI	DID
2.0	7.0
2.0	7.5
2.0	8.5
2.5	8.5
3.0	7.0
4.5	7.5
4.5	7.5
4.5	8.5
4.5	10.0
5.0	6.0
5.5	3.5
5.5	6.0
6.0	5.5
6.0	9.0
Ave. 4.1	7.3

POOR ALIGNMENT

ICI	DID
2.0	6.5
2.0	9.5
2.5	5.5
2.5	6.0
2.5	6.5
2.5	7.5
2.5	8.0
3.0	6.0
3.0	7.5
3.5	8.0
4.0	5.0
4.0	7.5
4.0	10.5
4.5	6.0
4.5	8.5
4.5	10.5
5.0	6.5
5.0	8.0
6.0	8.0
6.0	8.5
Ave. 3.7	7.5

MANDIBULAR

GOOD ALIGNMENT

ICI	DID
1.0	5.0
1.0	5.0
1.5	5.0
2.0	5.5
2.5	4.0
2.5	5.0
3.0	4.0
3.0	4.5
3.0	5.5
3.0	5.5
3.5	5.5
3.5	5.5
4.0	5.0
4.0	6.0
4.0	6.0
4.5	4.0
4.5	5.5
5.5	5.5
Ave. 3.1	5.0

FAIR ALIGNMENT

ICI	DID
1.0	4.0
1.0	4.0
1.0	5.5
1.5	4.0
1.5	8.0
2.0	5.0
2.5	4.5
2.5	5.5
3.0	4.5
3.0	4.5
3.0	5.0
3.0	6.0
3.5	3.0
3.5	6.5
3.5	7.0
4.0	4.0
4.0	4.0
4.0	7.5
4.5	7.0
4.5	7.5
6.0	7.5
Ave. 3.0	5.4

POOR ALIGNMENT

ICI	DID
0.5	4.5
1.0	4.5
1.0	6.0
1.5	4.0
1.5	5.5
1.5	5.5
1.5	5.5
2.0	5.0
2.5	4.5
2.5	5.0
2.5	5.5
3.5	6.0
3.5	6.5
Ave. 1.9	5.3

ICI= Inter-canine increase.
DID= Difference in diameter.
All Figures are in M.M.

11979.9

Figure 6
Figures showing the relation between inter-canine growth, difference in diameters of deciduous and permanent incisors, and alignment of the permanent incisors.

followed by good alignment, and no increase is followed by poor alignment or crowded incisors, the diagram should show this relation. What do we find? Look at the diagram and you will see that in all categories there is a mixture of results, showing that there is no definite relation between spacing and alignment. Our first observations showed this to be true, but we were not satisfied until we had examined our results quantitatively.

The diagram showed something further—that in our series a constant wide spacing was followed by better alignment; that, except in one case, spacing increased at one stage only; and that 16 out of 75 cases showed an increase in spacing, 59 showed no change, and none showed a decrease. Such a picture cannot be seen without the help of the diagram. In the light of our findings, what are we to conclude? Simply this, that in our series there seems to be no positive relation between deciduous incisor spacing and the alignment of the permanent incisors. An inspection of the models, after we had made this finding, showed that growth adjustments, not spacing, determined, poor, fair, or good alignment. If, as in figure 5, we find absolutely no spacing followed by good alignment of the permanent incisors, we must conclude that there is something much more important than incisor spacing at work in bringing about good alignment. We must accept such a conclusion in spite of the fact that so many orthodontists predict developing malocclusion on the basis of incisor spacing, even before the jaws and dental arch have had an opportunity to grow.

Finding a negative result from such a study does not mean that we should let matters rest there. We must go further. Here the next study was an examination of the relation in intercanine growth, the difference between the diameters of the deciduous incisors and those of the permanent incisors, and the alignment of the permanent incisors. Figure 6 will show the results. Since only two variables can be plotted on a scatter diagram, we used a different method, but the illustration will show all that is necessary for our purposes. You will see that there is a tendency for the larger intercanine increases to be followed by better alignments. This study carries us a step further, but it does not show the cause of poor alignments. We are now studying the relation in intercanine increase, difference in diameters, and the amount of spacing and alignment. At sometime in the near future I hope I can report the findings of this study to this group.

At this point I should like to say that in our study, as in almost every study, there is room for improvement. Some of the methods now in use could have been adopted with benefit had they been available when I started the investigation. Simon's method of gnathostatic casts in relating the denture to the face was available, but I was not convinced of its accuracy. I, therefore, observed local manifestations of growth in the teeth and dental arches through the medium of orthodontic casts, roentgenograms, and oral examinations. Now, Broadbent has developed an X-ray apparatus which makes it possible to produce casts truly oriented to the skull. The use of such apparatus would have made it possible to get more accurate results from our study. As in other fields, our methods of investigation improve as we gain experience.

That the individual method which we are following has gained favor among other workers in our field is shown by the work of Dr. Broadbent, with which many of you are acquainted. He is making systematic examinations of the same individuals, in many cases over a long period of time, in order to determine how the head, face, and jaws grow. He will also check the results of Hellman's work and will be able to show individual variations as well as general trends.

Animal experimentation is another method of investigation that must be mentioned. It has been an indispensable tool in the field of growth and development, as is illustrated by the monumental work of Oppenheim on the changes in the bone during the movement of teeth by orthodontic means. Prior to his investigation there were two diametrically opposed theories of bone changes during tooth movement. Through animal experimentation Oppenheim found out exactly what happened to bone when the teeth were moved by means of orthodontic appliances, and so settled once and for all this much-disputed question. He brought to light factual evidence lacking before, and proved both the theories formerly held to be wrong. Klein showed, through his swine-feeding experiments, that growth of the jaws is affected in certain ways by feeding diets lacking in certain elements. However, there is always a question whether these results would be paralleled in human beings. Also, we must be on our guard with respect to the conclusions drawn from them. In 1924, Johnson in some degree repeated the work of Oppenheim, using the Macacus Rhesus monkey instead of the chimpanzee. One of his observations was that if a tooth was moved before the root was complete, the portion formed after the tooth was moved occupied a different position than the moved tooth. There seemed to be a curvature at the end of the root after the moved tooth had its root end completed. Later, while working on the same problem, though chiefly from the point of view of the influence of certain deficient diets on the bones and teeth of the monkey, Dr. John Marshall discovered that the roots of the teeth of Macacus Rhesus were normally curved at the apical end. Thus, Johnson's conclusions were brought into question.

In conclusion, I should like to repeat what I said in starting—that in instituting a piece of research one must have a definite idea of what is to be done, a definite purpose, and a definite plan of attack. If more men who are doing research work in our field would adopt these three principles, the science of orthodontia would soon take its proper place among biological sciences and our textbooks, instead of containing many statements based on speculation, would be filled with material having a scientific foundation and a biological justification.

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