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EXPANSIVE SIDE EFFECTS IN THE BUCCAL SEGMENTS OF BEGG SPUR-TYPE TORQUING AUXILIARIES:-

A LABORATORY STUDY

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A Thesis submitted in partial requirement for the degree of Master of Dental Science

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1989
PREFACE

This thesis was commenced in 1979 during the first year of the two year M.D.Sc. course in the Department of Preventive Dentistry, Faculty of Dentistry, University of Sydney. Its completion has been a very long and drawnout affair.

The original Literature Review and the experimental work were completed in the ensuing 18 months, but the project foolishly was left unfinished at the end of the full-time course period.

In subsequent years, the Literature Review was updated many times but the project was not brought to completion, despite the best of intentions. In later years, the task has proven to be something of a personal struggle which, with the distractions of full time orthodontic practice and that of a young family growing from infancy through childhood, has become increasingly more difficult.

To those who follow in the Master's programme may I say this: should you be tempted to delay or postpone completion of your project, you do so at your own peril!

I am deeply indebted to my supervisor, Professor Godfrey for his extreme patience and understanding during the nine years this project has been outstanding.

S.F.F.

Who in season labours best,
His labours ended, has the sweetest rest

Socrates (496 - 406 BC)
Philoctetes, 637
(tr. by F. Storr)

Vincit qui se vincit ("He conquers who conquers himself")
(An old school motto)
ACKNOWLEDGEMENTS

May I record my sincere appreciation to the following people who gave assistance in the preparation of this thesis:

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I would also like to record my appreciation to Mrs Judy Steinlechner, former Secretary to Professor Godfrey, whose persistent urging to finalise this thesis has been a constant embarrassment to me. Also, special thanks is due to my Canberra colleague, Dr John Fricker, who recently rekindled my interest in the project, and to my wife Jane and Mrs Kate Fricker for their proof reading of the draft.

Finally, but importantly, my thanks is due to Mrs Dianne Manning and the staff at "The Typist", to whom fell the laborious task of typing (and retyping ...) the text, and who I hope may soon free up their disc space by typing "ERASE*,**".
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INTRODUCTION

Undesirable changes in arch form have been described during the incisor torquing procedures of Stage III of the Begg Light Wire technique. It has been suggested by several authors that constriction in the horizontal plane of the distal ends of the main arch wire is advisable to counteract any expansion that may occur as a side affect of incisor torquing procedures.

However, the amount of constriction recommended varies from author to author and appears unrelated to the specific torquing requirements of each case.

The purposes of this project were as follows:

1. First, by means of a systematic review of the relevant literature, to gain an historical perspective with respect to incisor torquing procedures during Begg Light Wire treatment. Then, to examine the literature with specific reference to torquing procedures using spur type torquing auxiliaries and to examine their reported side affects.

2. Second, to devise and implement a laboratory study to investigate the relationship between the inclination of the central incisor teeth to be torqued by a Begg spur type torquing auxiliary under certain conditions and possible changes in the arch form in the buccal segments of the main Stage III arch wire.
3. Third, to draw conclusions as to whether more specific recommendations can be made to counteract arch form changes as a result of incisor torquing procedures with specific reference to the torquing requirements of each case.

The initial motivation for this project came from studies previously carried out by Scully (1972), and Hurd and Nikolai (1977), which were concerned with the effect of incisor torquing procedures on the anterior segment of the arch wire. There did not appear to be studies involving the effects on the posterior segments of the arch wire although the article by Foster (1968) discussed this issue.

Also, the subject was chosen because it appeared to provide enough scope to sustain continued investigative interest on the part of the author beyond the requirements of the present post-graduate course.

This project is divided into Section 1, incorporating the review of literature and Section 2, wherein the original study is described and the results reported. To improve the readability of the text, detailed description and illustration of the apparatus and its preparation, the materials used and their preparation and the detailed description of the experimental method have been relegated to appendices in Section 3.

An outline of the research design and its implementation, along with some illustrations, is included in the main body of the text in Section 2, with references to the appendices where clarification by further detail may be necessary.
SECTION 1. REVIEW OF LITERATURE

INTRODUCTION

This literature review aims to provide an overall perspective of incisor root torquing procedures in the Begg Light Wire technique as a precursor to examining the issue of the reactive side-effects in the buccal segments produced by spur-type torquing auxiliaries.

First, incisor root torque is defined and then the literature is reviewed with respect to the importance of incisor root torque as an integral part of orthodontic treatment in general. The second chapter highlights the importance of incisor torquing procedures in the context of the unique tooth movements of Begg Light Wire treatment.

Chapter 3 illustrates the importance of Dr Begg as the developer and innovator of the technique through his published papers, his texts and his personal influence in the orthodontic community. Developments subsequent to 1961 are reviewed in Chapter 4 and a conceptual model of the early development of Begg torquing procedures is also presented.

A list of the various forms of incisor root torquing appliances in the Begg technique is presented in Chapter 5. This list is not intended to be exhaustive but rather is intended as a means of illustrating the wide variety of means of applying incisor root torque in the Begg Light Wire technique. A brief summary of the mode of action of the three main types of auxiliaries is presented in Chapter 6 and a brief review of the literature involving histologic studies of root torquing procedures is presented in Chapter 7.

The latter part of the literature review aims to narrow the field to those articles concerned with spur type torquing auxiliaries, with which this particular study is concerned. Force magnitude is examined in Chapter 8 and subsequent chapters deal in detail with the issues of adverse structural and mechanical effects of incisor torquing procedures and finally, possible means of preventing these adverse reactions.
By employing a step by step approach to the review of literature, it was hoped to provide not only an historical perspective to the various problems associated with incisor root torquing procedures with the Begg Light Wire technique but also an attempt was made to outline the development of torquing procedures in the Begg technique as a problem solving process; that is, changes were made to the technique to overcome unwanted reactive side-effects of the appliance. Considerable emphasis has been given to Dr Begg's central role in this development process.
SECTION 1 - REVIEW OF LITERATURE

CHAPTER 1

TORQUE: DISCUSSION OF TERMS

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CHAPTER 1

TORQUE: DISCUSSION OF TERMS

According to the Shorter Oxford English Dictionary (Onions, 1973), the word 'torque' is derived from the Latin 'torquere', to twist. 'Torque', 'torque force' and its application, for example, 'Torquing auxiliary', are used freely, and sometimes interchangeably, in the orthodontic literature, and therefore a discussion of these terms is warranted.

1.1 Torque Versus Torsion

Thurow (1972, p.35) stated that 'torque' and 'torsion' are similar words used to describe the twisting of a beam or wire. 'Torque' is the force (or stress) which causes the twist, while 'torsion' is the actual twisting (or strain) which takes place in the material as a result of torque.

In orthodontics, the word 'torque' has taken on a unique meaning: it is used to describe the effect on a tooth when a twisted (torqued) arch wire or auxiliary delivers a resultant force (torque force) to that tooth.

Rauch (1959) defined torque in terms of how it is used: "the force that gives the operator control over the movements of the roots of the teeth". Strang and Thompson (1958, p. 485) defined torque force as "that force obtained from a twisted spring wire in its effort to untwist itself". Also, torque has been defined as a force in a circular motion in any of the three planes of space (Mitchell and Kinder, 1973).

1.2 Crown Torque Versus Root Torque

Nahoum (1962) and Mitchell and Kinder (1973) described torque force according to its actions on the crown of the tooth, i.e. 'lingual torque' meant lingual crown torque. This method of description has some validity, especially for those employing the Edgewise philosophy. Rauch (1959) refers to the progressive lingual torque, from cuspid to molar, that is necessary in an edgewise arch for passive seating in tie brackets.
More generally, however, torque is referred to by its effect on the root of the tooth and this is often specified, usually by the direction in which the root moves: e.g. 'lingual root torque'. This convention seems to be universally adopted in the Begg literature and often in orthodontic texts: e.g. Jarabak and Fizzell (1963), Thurow (1972) and Houston and Tulley (1986).

1.3  **Lingual Torque Versus Labial Torque (Reverse Torque).**

In most instances, torque force is employed to move the roots of anterior teeth lingually. However, sometimes torque force is applied in the reverse direction: i.e. to produce labial root movement. This may be necessary, for example, where the roots of instanding maxillary lateral incisors are placed too far lingually.

Because the direction of root movement in these cases is in the reverse direction to that usually employed, the term 'reverse torque' is often used.

1.4  **Edgewise Torque, Light Wire Torque, and Other Methods**

Reitan (1985, p. 156) distinguishes between two categories of torque application in current orthodontic techniques:

1.4.1  **Edgewise Torque.**

1.4.2  **Light Wire Torque.**

The present author includes a third category to accommodate methods which do not appear to fall into either of the preceding ones:

1.4.3  **Other Torquing Methods.**
1.4.1 Edgewise Torque

Scully (1972), when classifying methods of torque application, considered this category to include all systems which use rectangular brackets. However, by definition, edgewise torque involves the use of a rectangular arch wire in the bracket slot of the edgewise appliance. Hence only those techniques which employ rectangular wire employ edgewise torque.

With this method, the arch wire, suitably modified with pliers or a torquing key, may be placed in torsion as it is seated in the bracket slots of the teeth to be torqued. Alternatively, as in some contemporary orthodontic systems, such as those of Ricketts (1976) and Andrews (1976), a plain arch is inserted in brackets, the slots of which are set at predetermined angles to the tooth surfaces.

1.4.2 Light Wire Torque

This category encompasses those methods applying torque force by means of small diameter round wire. It includes not only the torquing procedures of the Begg technique, but also those carried out in many orthodontic systems employing tie brackets with round arch wires: e.g. Jarabak and Fizzell (1963, p. 69), Bernstein (1971), Smart et al, (1980).

Light wire torque is usually performed by an auxiliary 'piggyback' arch which, in most cases, is inserted for moving tooth roots lingually after their crowns have been tipped lingually. The light force produced, according to Reitan (1985, p. 156) is continuous in type. This is in contrast to edgewise torque, where the force magnitude is initially high, but because of the limited range of the edgewise arch, is an interrupted type of force.

Several methods of light wire torque, that do not involve 'piggyback' auxiliaries, have been mentioned in the literature: Jarabak and Fizzell (1963, p. 69) utilised reflex horizontal loops in a round arch wire to achieve incisor torque. Bernstein (1971) used a rectangular arch wire with "Warren springs", an apron-spring type similar to the Muir-type loops used by Reitan (1964) and Gaudet (1970).
1.4.3 Other Torquing Methods

The inclusion of this category is necessary to group together methods of torque application which fall into neither of the preceding ones. It mainly comprises banding techniques employing tie brackets and round arch wires, but also includes the use of removable appliances and extra oral traction.

Nahoum (1962) employed a torquing crimp placed in the round arch wire which, when tied into the bracket, endows the wire with the keying properties of a rectangular arch in this area.

Bowman (1962) used gingivally extending 0.018 in. diameter finger springs of cobalt-chromium. These were soldered to the arch wire in such a manner as to exert torque force at the cervical area of the teeth to which they were applied.

Hitchcock (1970) utilised a coil spring stretched across the cervical area of the incisors and attached to hooks extending gingivally from the arch wire in the cuspid regions. This method was varied slightly by Mitchell and Kinder (1973), whose technique made use of stretched elastic in a similar manner. Kaplan (1968) also used an elastic in conjunction with edgewise torque.

Jarabak and Fizzell (1963, p.225) describe the use of a horizontal helical loop appliance supplemented by a high pull head gear, especially designed for an almost vertical upward pull. They emphasised that the head gear vertical component must be anterior to the labial surfaces of the root masses of the incisor teeth, to effect lingual root tipping.

Hale (1987) described a case history for a severe class II, division 2 case in which a 0.019 x 0.025 in. auxiliary was used in the maxillary central incisor region, in combination with high pull headgear. The rectangular auxiliary was designed so that the direction of pull would be close to the centre of rotation of the incisors, providing palatal root torque.
A removable appliance designed to apply lingual root torque to maxillary incisors has been described by Goel (1981). This acrylic appliance is retained by means of Adams crib clasps applied to first permanent molars and by triangular clasps between first and second premolar teeth. A labial bow supports an 0.4 in. diameter spring wire auxiliary of the apron-spring type.

This Chapter has dealt with the special usage of the word 'torque' and its various applications, in the orthodontic literature. The various descriptive terms commonly used in reference to torquing movements have been discussed and three general categories of torquing movements have been delineated.
CHAPTER 2

THE NECESSITY FOR INCISOR ROOT TORQUE

2.1 Early Development of Root-Moving Appliances
2.2 Incisor Root Torque in Modern Treatment Philosophy
   2.21 Stability
   2.22 Aesthetics
2.3 Incisor Root Torque and the Begg Technique
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CHAPTER 2

THE NECESSITY FOR INCISOR ROOT TORQUE

The purpose of this Chapter is to discuss the need for incisor torquing procedures in orthodontic treatment. The development of early root moving appliances will be briefly reviewed. Then, the place of root torquing procedures will be discussed within the framework of modern treatment philosophy. Finally, the special significance of root torque to the Begg treatment method will be considered.

2.1 Early Development of Root-Moving Appliances

The fixed appliances of the early 1900's employed heavy labial arch wires, to which the teeth were ligated. Angle's 'E' Arch (Angle, 1907: p. 248), the first in a long series of Angle appliances, was used primarily for tipping tooth crowns into proper alignment. It was the first appliance to employ bodily control of the anchor molar teeth, which were fitted with clamp bands (Lindquist, 1985: p. 568).

It became apparent, however, that to achieve the proper position and axial inclination of the teeth, better control of each individual tooth was needed; control that would permit the movement of the root as well as the crown (Lindquist, 1985).

Probably the earliest appliance designed to move tooth roots was that of Calvin Case, reported in 1908 (Case, 1908), in which two labial arches were used in conjunction with a lever-type bracket on anterior teeth (Figure 1, p.11). Angle, recognising the need for more individual tooth control and the limitations of his earlier appliances, introduced the Pin and Tube appliance in 1911, which was designed to move teeth bodily (Angle, 1912). The arch wire had pins soldered to it in such a manner as to influence the total position of each tooth.
Figure 1: Calvin Case's appliance for torquing anterior tooth roots lingually.

This appliance was very time-consuming to prepare and difficult to insert (Robinson, 1915), and was soon replaced by the more efficient and more easily adjusted Ribbon Arch appliance in 1916 (Angle, 1916). With the 'ribbon' or rectangular arch, adjustments could be made that exerted strong pressures on the apices of the teeth. According to Dewel (1981), it was with the Ribbon Arch appliance that orthodontists learned the principles of torque control.

Robinson (1915), in response to the shortcomings of the Pin and Tube appliance, recognised the advantage of the looped spring and introduced vertical arch wire loops to his treatment methods.

H.G. Watkins' appliance, first described by its originator in 1933, utilised a loop and tube design to carry out tooth movements. According to Mills (1970), this appliance was useful where small numbers of teeth require rotations and/or root movements.

The final appliance devised by Angle, the Edgewise mechanism (Angle, 1928), gave more control over mesio-distal tipping of teeth, with corresponding root control, and also gave improved stabilisation of the molar teeth.
In summary: orthodontic appliances were introduced that made possible movements of tooth roots, thus enabling greater control of tooth movements. However, Begg (1954D) pointed out that such added control was at the expense of simple crown tipping, a movement which he considered as the simplest and often the most vitally necessary of all tooth movements.

2.2 Incisor Root Torque in Modern Treatment Philosophy

According to Sims (1972), the correction of malocclusion with fixed appliances involves the application of three important orthodontic concepts:

(i) anchorage preservation
(ii) bite opening
(iii) incisor torquing movements

Brouwer (1973) considered the clinical goal of treatment to be "the establishment of an occlusion directly over supporting bone, all being in harmonious balance with the surrounding facial and cranial structures". Often this cannot be achieved without employing torque force to correct the axial inclinations of incisor teeth.

Such satisfactory labio-lingual inclination of maxillary incisor teeth was thought by Blodgett and Andreasen to be an important requirement of successful orthodontic treatment:

"failure to sufficiently torque maxillary incisor roots is one of the major shortcomings in orthodontic practice" (Blodgett and Andreasen, 1968)

Sims (1972) also expressed this point of view, emphasising the axial inclination of maxillary incisors to a reference plane such as the sella-nasion line, rather than concentrating treatment planning on predetermined angles of the lower incisor to the mandibular and Frankfort planes as Tweed did (Tweed, 1966).

Finally, Rauch (1959) also emphasised the importance of torque by stating that torque of the edgewise wire is probably the most important and potent force of the edgewise mechanism.
The reasons for torquing incisor teeth may be discussed under two main headings:

2.2.1 Stability
2.2.2 Aesthetics

2.2.1 Stability

Graber (1966) thought that significant lingual root torque of the maxillary incisors during treatment reduces the tendency for overbite to relapse, and that as overbite is one of the more difficult problems in orthodontics, such incisor torque is important. However, he criticised the use of arbitrary tooth inclinations as treatment goals.

The crucial factor in overbite stability, according to Houston and Tulley (1986: p.182) is the correction of the incisor edge - centroid relationship and they considered that this could only be ensured by sufficient retraction of the upper incisor centroid using fixed appliances with palatal root torque. However, they felt that in severe cases, the alveolar process may not be thick enough to allow full correction in this way, because little periosteal bone remodelling occurs on the palatal aspect at the level of the incisor apices and, therefore, some degree of lower incisor advancement may be necessary in these severe cases.

Jacobson (1973) demonstrated lingual root torque cephalometrically but queried the degree and permanency of this change. He agreed with von der Heydt (1965), as did Graber (1966), that lingual root torque reduces the tendency of overbite to return, but stated that torque is not always obtainable to the degree that is desired, without irreparable damage to root structure in the form of apical root resorption.

Sims (1972) illustrated the long-term stability that can be achieved with permanent overbite reduction in treatment involving removal of four bicuspid teeth. He considered that stability could be anticipated provided adequate incisor torque is achieved in the maxilla. Furthermore, collapse of the lower labial segment need not be feared, he said, if a functionally adequate inter-incisal angle is combined with sufficient maxillary incisor torque.
Reference to the role of adequate maxillary incisor torque in reducing relapse of overbite was made also by Blodgett and Andreasen (1968), Mitchell and Kinder (1973) and Williams (1977, p.622).

Von der Heydt (1965) pointed out the remarkable co-ordination between proper torquing of upper incisors in the Begg technique, and the anchorage adjustment in the lower arch. This results in the nearly automatic positioning of the incisal edge of the lower incisor on the A P line (A = subspinale, P = pogonion). According to von der Heydt, it is this relative position of the lower incisal edge which establishes lip balance and facial harmony. Such an incisor relationship has been advocated as a treatment goal by Williams (1969; 1977, p.609) from the standpoint of incisor stability. However, Houston and Tulley believed there is no sound biological basis for this because "stability depends on soft tissue, not skeletal balance (Houston & Tulley, 1986: p.182). They believe the A-P line provides only a guide to the reasonable limit of labial advancement.

The principle of overmovement of teeth for the purpose of increasing the stability of treatment results, has been propounded by Begg (1965, p. 348) and reiterated by Sims (1964; 1966; 1971) and by Cadman (1975B). This principle is relevant to incisor torquing procedures: Begg and Kesling advocated over-torquing of maxillary incisors, especially in Class II, Division 2 malocclusion treatment, to allow for some degree of relapse (Begg and Kesling, 1977A: pp. 652, 653).

On the other hand, Booy (1969) questions whether torquing incisor roots in the Begg technique really contributes so much to the final stability, or whether this is done merely to compete with Edgewise therapy.

Kesling and his group (Brandt, 1971), advocated a maxillary incisor inclination relative to the sella-nasion plane of 106° or more at the end of treatment. They found retroclination occurred in the post-treatment period to a final inclination of 103° which they considered to be the correct inclination. In contrast, Williams (1977, p.621) and Levine (1977) found a slight proclination in the post-treatment period, and a tendency for incisor inclination to approach 103°.
Levine attributed this difference in post-treatment response to a possible difference in retention appliances used. He assumed that retention with removable appliances allows proclination of maxillary incisors. To take advantage of this favourable post-treatment response, Levine suggested that maxillary incisors should be preferably undertorqued, rather than overtorqued.

Gildea (1982) in a Round Table Discussion on the Begg Technique, supports this view. He warned against overtorquing incisors because he considered that "they look terrible and they do not bounce back". In fact, he was surprised to find that torque of upper incisors actually increased during the retention period.

Dr. Harry Barrer, commenting in the same article, agreed, stating that almost invariably, torque increases and the facial profile improves with post-treatment maturation. Another participant, Dr. Gary Fowler, pointed out that he found it necessary to carry out more torque in Class II Division 2 cases because he found loss of torque during retention in these cases.

2.2.2 Aesthetics

Several authors have discussed the effect of incisor torque in terms of the appearance of the treated case. Mitchell and Kinder (1973) thought that to overlook the labio-lingual inclination of incisors was to detract from the aesthetic appeal of the case. Rauch phrased it another way:

"the operator's ability to control torque properly will mean the difference between an artistically finished denture and an ordinary tooth-straightening accomplishment" (Rauch, 1959).

He pointed out that the use of torque force enables the orthodontist to control the axial inclinations of teeth, so that they may be placed in the positions of harmony that are so desirable for a nicely finished result.

Janzen (1977), in an article on the importance of the balanced smile in treatment planning, considered that improved facial balance when smiling is an essential treatment objective. He demonstrated how this can be achieved as a result of intrusion of maxillary incisors, in conjunction with sufficient palatal root torque. Watson (1980) also expressed this view, commenting on the improvement in the smile which often occurs with maxillary incisor intrusion and torque control.
Torquing of maxillary incisors is important from another standpoint: it assists in bringing about desirable change in point A, representing the anterior limit of the maxillary base (Stoner et al., 1956, Williams, 1977). This, in turn, helps to bring about desirable facial changes in the patient by reducing the apical base difference.

Such a view was previously stated by Holdaway (1956), Buchin (1959), Kimmons (1963) and Weber (1971). Cangialosi and Meistrell (1982), in a more recent study of changes in hard and soft tissues in Stage 3, arrived at a similar conclusion. Pridemore (1989) also examined a sample of patients treated with the Begg technique and found that the mean reduction in angle ANB, representing the apical base difference, was 3°. This reduction was accomplished primarily by posterior movement of point A.

Rauch (1959) concluded that to achieve the reduction in apical base difference necessary for beneficial facial change, a definite technique for the application of torque must be developed.

2.3 Incisor Root Torque and the Begg Technique

2.3.1 The Nature of Begg Mechanics

The points discussed above apply as much to a case treated with the Begg technique as to one treated by any other method. However, Begg treatment relies on torquing mechanics far more than techniques in which the tooth movements are essentially bodily in nature.

Through trial and error, Begg evolved an entirely different system of mechanics for tooth movements based on the use of a modified ribbon arch bracket and round wire. Two successive tipping movements are used: the first positions the tooth crowns, while the second, tooth roots (Cadman, 1975A).
The technique is divided into three stages and it is during the third stage that uprighting of teeth tipped in the first two stages is carried out (Begg and Keeling, 1977b). Mesio-distal uprighting is achieved by auxiliary uprighting springs, while correction of labio-lingual inclinations of incisors are adjusted using auxiliary torquing arches. As Fletcher puts it "The purpose of this last phase of active treatment is to promote or restore the axial inclinations of those teeth that were, or have become, tilted" (Fletcher, 1981: p.28).

Torquing the maxillary incisor teeth requires considerable lower molar anchorage, as pointed out by von der Heydt (1965). As point A retreats with the apices of the maxillary incisor teeth, the mandibular incisors assume an attitude of balance with the incisal edges of the central incisors on the A-P line. He felt that there is a remarkably co-ordinated relationship between proper torquing of the upper incisors and the anchorage adjustment in the lower arch. Williams (1969, 1977: p.609) has discussed the use of the A-P line as a guide to lower incisor positioning and this issue has been referred to by many authors, including Brandt (1971), Thompson (1974), Cadman (1975), Fletcher (1981:p.52), and Houston and Tulley (1986: p.183).

As far as maxillary molar anchorage is concerned, Hurd and Nikolai (1977) showed that by far the greatest portion of the mesial movement of anchor molars occurs during Stage 3, and that the degree of torquing undertaken and anchorage lost in Stage 3 are significantly correlated.

Cadman (1975 A) pointed out that this mesial movement of the dental arches in Stage 3 is related to the effects of incisor torquing procedures, intermaxillary traction and uprighting springs. He explained that in the Begg technique, the teeth are purposely retracted slightly too far, by the end of Stage 2, to allow for the mesial movements that occurs in Stage 3.

2.3.2 Variations in Torquing Requirements

According to Sims (1972), a comprehensive evaluation of axial inclination of teeth is most important, since extensive torquing movements involve the provision of increased anchorage, when compared with those malocclusions which do not require incisal torque. He emphasised the fact that anticipation of future torquing requirements enables a more accurate evaluation of anchorage potential prior to the commencement of treatment.
Sims also pointed out that the pronounced, though temporary retroclination of both maxillary and mandibular incisors at the end of Stage 2, generally indicates the successful maintenance of first and second stage anchorage. He considered that marked retroclination (hence extensive torquing requirements), can be predicted under a variety of circumstances: these include certain malocclusions demonstrating a large apical base discrepancy, and also some cases of bimaxillary protrusion (Sims, 1972).

Begg and Kesling (1977A, p. 131) also point out the differences in torquing requirements in various situations:

(a) Torquing of maxillary incisors is usually unnecessary in four first premolar extraction cases, where a considerable size discrepancy between tooth substance and jaw exists, because the extraction spaces are generally closed before the crowns of the incisors are able to tip very far linguually.

(b) Torquing is sometimes necessary in non-extraction cases, especially in those that have an excess of jaw substance relative to tooth substance. Swain (1969B) pointed out that the amount of force and the time required for torquing are reduced, since less uprighting is required because fewer and smaller spaces are closed during the first two stages.

(c) Torquing is nearly always necessary in mild discrepancy cases that require four first premolars extracted: i.e. only a mild excess of tooth substance relative to jaw size exists. In these cases, the crowns of the incisors are tipped a long way lingually during closure of the extraction spaces.

Begg and Kesling (1977A, p. 227) also discuss methods of limiting this excessive lingual tipping in mild discrepancy cases, by means of braking arches, or canine uprighting springs, or by means of a combination of canine uprighting springs and heavy space closing elastics in the second stage of treatment.
(d) Torquing is nearly always necessary in the severest discrepancy cases where eight teeth are extracted. The large amount of extraction space in these cases means that incisor crowns are tipped a long way lingually. Braking mechanisms in Stage 2 mentioned in (e) above are applicable in this situation also.

Varying opinions have been expressed in the literature concerning the need to torque all four maxillary incisors. Thompson (1972) thought that many cases require only a two spur torquing arch, especially when lateral incisors are flared. Cadman considered that central incisor torque alone is sufficient "in most instances" (Cadman, 1971A). This opinion was also expressed by Brouwer (1973), who maintained that the lateral incisors are influenced adequately by the torquing of the central incisors, and by the action of the uprighting springs.

Von der Heydt (1982), however, considered that his auxiliary torqued central incisors only, and like Brouwer, believed that the lateral incisors were controlled by the root paralleling springs.

The Kesling-Rocke Group, however, criticised those who only torque central incisors, on the ground that incisors may not be retracted sufficiently during Stages 1 and 2, due to poor anchorage preservation (Brandt, 1971). They maintained that lateral incisors may not need to be torqued because they were not retracted sufficiently in the first place. They also pointed out that this may not be very critical in a mild tooth mass - arch length discrepancy case, where excess space usually exists. However, where space is critical, if sufficient retraction of the incisor segment occurs in the first two stages, the upper and lower dental arches may be brought too far forward by the completion of Stage 3.

In summary: the methods of root movement in orthodontic treatment evolved because of the need for more precise control over tooth movements. This precision in incisor root positioning, is achieved by torquing procedures and contributes substantially to the stability and aesthetic appeal of the finished case.
Because of the nature of tooth movements carried out in the Begg technique, root torquing is a necessary procedure, in most extraction cases and in some non-extraction cases, to correct the axial inclinations of incisors tipped during the early stages of treatment. The degree of torquing necessary, varies from case to case and should be estimated prior to the commencement of treatment as part of the consideration of total anchorage requirement.
CHAPTER 3

ROOT TORQUE:  THE BEGG TECHNIQUE 1928-1961

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CHAPTER 3

ROOT TORQUE: THE BEGG TECHNIQUE, 1928 - 1961

In 1954, P.R. Begg's four-part series of articles was published in the American Journal of Orthodontics. The first three in this series, (Begg, 1954 A, B, C) dealt with his philosophy of anatomically correct occlusion as developed from his studies of Stone Age Man's dentition.

The final article (Begg, 1954D) outlined his treatment technique, which he had been developing since the late 1920's, utilising modified ribbon arch brackets and round, heat-treated 0.018 in. diameter stainless steel arch wire.

This Chapter briefly reviews the early history of Begg's treatment method and his publications, specifically in relation to the means of torquing incisor teeth, with emphasis on the changes introduced at various times.

3.1 1928 - 1956

When Begg first began extracting four first premolars in 1928, he found that loosening of the fit between arch wire and tie brackets due to wear and tear permitted the incisors to tip lingually, instead of moving back bodily to fill the extraction spaces. To prevent this tipping, frequent arch removal for adjustment was necessary.

However in 1929, four soldered spurs, 0.050 in. long, were placed at right angles to the gingival surfaces of the upper and lower edgewise arches, so that when the arches were tied into the brackets, the free end of each spur pressed against the labial surface of each incisor. In this way, bodily movement was made easier.

It was from these vertical spurs soldered to edgewise arches that Begg, utilising the superior properties of heat-treated stainless steel, began using an 0.018 in. diameter single round arch wires. These arches were constructed "with appropriately placed vertical spurs" (Begg, 1954D), as illustrated in Figures 2 and 3, p 23.
A modified ribbon arch bracket replaced the tie bracket, because rotations were performed more easily with the former, and also, because the narrowness of this bracket accommodated the vertical arch spurs, so that they were in contact with the teeth along their entire length.

The spurs engaged the teeth as near to the centres of their labial surface as the ribbon arch brackets would allow. They were bent lingually, prior to inserting the wire, to the required angle for exerting lingual pressure on the roots. If labial root torque was required, the spurs extended incisally rather than gingivally.
Begg explained which procedures were necessary before an arch wire with vertical spurs was used:

"extensive imbrications, rotations or spacing of the teeth are first corrected by the use of the thin steel arch wire without spurs, but with expansion or contraction loops where required" (Begg, 1954D).

He considered that previously, the Class II, Division 2 case was one of the hardest to treat because of the difficulty in reducing the extreme lingual inclination of the incisors. However, with the torque force which could be exerted by the vertical arch spurs, he considered correction of such lingual incisor inclination a simple procedure. Also, because the force operated over a wide range of tooth movement, frequent arch removal for reactivation was not necessary.

Finally, Begg referred to another use of vertical arch spurs:

"these vertical arch spurs can be employed to obtain firm en masse anchorage of the lower incisor teeth for resistance to intermaxillary force. The arch spurs, of course, are then pointed up incisally on the lower incisors" (Begg, 1954D).

3.2 1956–1960

In 1956 a more detailed article was published, explaining at greater length what was, by that time, referred to as 'Differential Force in Orthodontic Treatment', Begg (1956). Begg now used 0.016 in. diameter arch wire and the vertical arch spurs extended gingivally from it, either bodily moving the anterior teeth lingually or tipping their roots lingually, according to the extent of activation of the spurs. No direct reason was given for the change from 0.018 in. to 0.016 in. wire, although it was inferred that this was done because of the greater flexibility of the lighter wire.

The importance of the vertical arch spurs to the treatment technique was emphasised:

"If it were not for these vertical arch spurs, it would not have been possible to dispense with the use of rectangular arch wire and with the excessive force which it delivers for orthodontic treatment" (Begg, 1956).
It was considered preferable to place the spurs distal to the brackets, to insure that spacing did not occur. Also, Begg favoured making the free ends of the spurs lean over mesially, so that their force would be delivered to the centres of the facial surfaces of the teeth. While bending vertical arch spurs, he said, the main horizontal line of the arch wire must be kept in a perfectly straight line. The four vertical spurs are then bent sufficiently far back lingually, to meet the requirements of the case.

This illustrates an important feature of the Begg technique. Sims phrased it nicely:

"intelligent reasoning demands that an appliance should be tailored to the patient and not the patient to the appliance" (Sims, 1964).

![Diagram of vertical arch spurs activation](image)

**Figure 4:** The manner in which vertical arch spurs are activated. (from: Begg, 1956).

Begg advocated that all the spurs be bent back together, to ensure that they are all bent to the same angle of inclination (Figure 4).
3.3 1960 – 1981

In 1960 Begg presented a paper to the American Association of Orthodontists' Congress in Washington, U.S.A., and published the contents in the following year (Begg, 1961). Again he described his technique, now labelled "Light Arch Wire Technique" and indicated changes which had been made recently. This concept of a treatment method which is continually being modified and improved, as experience dictates, is consistent with the manner in which Begg's treatment method had evolved since the late 1920's.

As related in the 1961 article, arch wires were usually 0.016 in. diameter but sometimes they were smaller. The main difference, however, compared with earlier publications, was the division of treatment into three distinct stages. Begg explained the nature of the tooth movement accomplished in the first two stages:

"The crowns of the anterior teeth are allowed to tip back instead of being moved back bodily, because their bodily movement would so strain the molar anchorage that the molars would be moved too far mesially" (Begg, 1961).

The third and final stage of treatment was designed to upright those teeth which were tipped during Stages 1 and 2. Therefore, arch wires incorporating vertical torquing spurs were not applied until Stage 3.

At the beginning of this stage, upper and lower auxiliary arch wires, containing vertical spurs, were applied gingivally to the original arch wires, instead of the vertical spurs being placed in the main arch, as formerly was the case. Thus the patient simultaneously wore four arch wires, two upper and two lower ones (Figure 5, p.27).

This was the first reference to the use of auxiliary arches for torquing tooth roots in Begg's technique. He explained that the change was made because he found that when a single arch wire with vertical spurs was used, the torque force exerted by the spurs transmitted a spiral force along the buccal segments of the arch wire, and acting through the anchorage bends, rotated molars mesio-lingually.
Begg found it unnecessary to torque upper and lower incisors in some cases, because the incisor axial inclination at the end of Stage 2 was ideal. In many cases he found that the slight lingual inclination of incisors at the end of Stage 2 was rectified entirely as a result of the actions of canine uprighting springs.

Finally, Begg referred to mild discrepancy cases which required extraction, but in which the upper and lower teeth needed retracting only a small distance. Therefore considerable mesial movement of posterior teeth was required. Auxiliary arches with slightly activated spurs were applied during space closure, preventing the lingual tipping of the anteriors and ensuring that the remaining extraction space was closed from the rear.

In summary: it has been shown how Begg modified and improved his treatment method as practical experience and necessity dictated. Early innovations, such as the use of stainless steel round wires and the modified ribbon arch bracket, were basic to the establishment of Begg's mechanics. Later changes, however, were aimed at reducing undesirable side effects of the mechanics: e.g., auxiliary torquing arches were introduced in an endeavour to overcome the reactive sequelae of incisor torquing movements.
CHAPTER 4

DEVELOPMENTS IN BEGG TORQUE THEORY AND APPLICATION SINCE 1961

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CHAPTER 4

DEVELOPMENT IN BEGG TORQUE THEORY AND APPLICATION SINCE 1961

This Chapter briefly describes the spread of Begg treatment and indicates the role of the orthodontic literature in this process. Using a conceptual model, development trends in Begg torquing procedures will be described, with particular reference to further control of reactive side-effects. Finally, publications since 1977 will be reviewed with brief mention of the trend towards amalgamated techniques.

4.1 The Spread of Begg Treatment

Since Begg first communicated his technique to the orthodontic world in 1954, (Begg, 1954D) and subsequently (Begg, 1958; 1961), there has been a wide interest in it both in Australia and overseas. In 1958, Dr. H.D. Kesling and Dr. G. Dinham visited Dr. Begg's office in Adelaide, South Australia, to observe differential force treatment. They were impressed by it and returned to the United States of America and began employing the technique (Begg and Kesling, 1977B).

Following that initial visit, many other practitioners travelled to Adelaide to observe the technique and to attend instruction courses, as recorded by Brandt (1962) and Sakai (1973). Some, like Dr. H.G. Barrer, undertook Begg treatment after reading Dr. Begg's early publications (Barrer, 1980); others learned by personal communication with Dr. Begg (Perlow, 1968); yet others attended technique courses conducted at Indiana, U.S.A., by the Kesling-Rocke Orthodontic Group. These courses were a major factor in the spread of the Begg Technique in North America.

At the same time in Europe, according to Booy (1969), Begg treatment was begun in the Netherlands in 1961, and Enoki (1962) reported its introduction to Japan in the same year. The Begg technique has continued to have a following in Japan as reported by Kameda (1982).
Dr Begg visited the Eastman Dental Hospital in London in the early 1960's to explain his technique and the first U.K. Begg course was held in 1967 by Brouwer and Hillegonsberg (Marx 1989).

4.2 The Orthodontic Literature

As a result of the wider communication of ideas, and clinical practice, Begg therapy became the subject of numerous journal articles, as clinicians began evaluating their treatment results.

Several of these articles described individual authors' experiences with the technique: e.g. Brandt (1962); Barrer (1963); Brouwer (1973; 1974; 1976). Other articles, while being descriptive, were more didactic in nature, presenting summaries of the principles and the application of the technique at the time: e.g. Sims (1964); von der Heydt (1965); Baldrige (1973); Cadman (1975 A, B, C). On the other hand, other authors concentrated on critical evaluation: e.g. Neuman (1963); Perlow (1968); Swain and Ackerman (1969); Parker (1969).

However, Begg continued to be the main advocate and innovator of the technique via his text (Begg, 1965) and subsequently, in association with Dr. P.C. Kesling (Begg and Kesling, 1971; 1977A). Over the years, there has been a process of continual development and numerous refinements, many of which were introduced by Begg himself. This development will be briefly outlined in relation to Stage 3 torquing procedures generally, but with particular emphasis on torquing auxiliaries, with associated main arch configurations.

4.3 Development of Begg Torquing Procedures to 1977: A Conceptual Model

The following conceptual model (Figure 6, p.31) is presented as a representation of the development in the application of torque force in the Begg Technique 1954-1977, as presented in the orthodontic literature. Although dealt with in the previous chapter, Begg's publications in 1954, 1956 and 1961 are included in this model for reasons of continuity. The present author is by no means suggesting that the paths of development illustrated were necessarily independent of one another, but rather that development took place with the interaction of ideas made possible by publications, personal communication and professional group meetings.
Figure 6: Conceptual model - development of Begg torquing auxiliaries, as reported in the literature.
From the model (Figure 6 p.31), it can be seen that the present author considers Begg's influence to be central to the development of torque application. The changes outlined in 1961, specifically:

(i) the division of treatment into separate stages,
(ii) the introduction of auxiliary torquing arches,
(iii) the change to lighter more resilient arch wire,

represent milestones in the development of the technique in general and of torque application in particular.

Variations reported in the literature in the following half decade were mainly concerned with modifications in shape and size of the torquing arch and the shape of the supporting main arch:

Brandt used a 0.016 in. diameter main arch wire with molar tie-backs "to keep the incisors condensed" (Brandt, 1962). His 0.016 in. diameter torquing auxiliary contained intermaxillary hooks but unlike Begg's auxiliary (Begg, 1961), it did not terminate between premolar and molar, but extended into the molar buccal tubes. The distal ends of the auxiliary were mildly constricted by placing a 'V' bend in the midline. However, no mention was made of the main arch configuration.

Barrer (1963) terminated his auxiliary distal to the canine and hooked it over the main arch wire. The auxiliary was constructed from 0.014 in. diameter wire and was considerably more circular in shape than that used by either Begg (1961) or Brandt (1962). The 0.016 in. diameter main arch wire was 'pear-shaped' to offset molar flaring. Molar tie-backs were omitted and instead, the main arch was cinched back behind the molar buccal tubes.

Two combinations of torquing auxiliary and main arch were described by von der Heydt (1965) and they illustrated the continuing trend towards constricted auxiliaries and 'pear-shaped' main arches. The first was very similar to that described by Barrer (1963). Von der Heydt, however, compared the shape of the torquing auxiliary to the circumference of a small coin, hence the name 'nickel arch'.
In the second combination described by von der Heydt, the intermaxillary hooks were omitted from the auxiliary and incorporated in the main arch. This combination represents the forerunner of that presently in common use. However, von der Heydt did not specify wire diameters for his arches.

The first edition of Begg's text (Begg, 1965) represented another milestone in the development of torque application in the technique. Begg recognised that a considerable reduction in the flaring of molars had occurred since auxiliary torquing arches had been introduced in 1961, due to the separation of the torquing and supportive functions of the arch wires (Begg, 1965: p.103).

In order to eliminate entirely the reactive effects of incisor torquing movements, Begg used heavier gauge main arch wires during Stage 3. He described an 0.025 in. diameter arch with an 0.014 in. or 0.016 in. diameter torquing auxiliary attached to it (Begg, 1965: p.91), as illustrated in Figure 7. This arrangement has been referred to as the "rat-trap" auxiliary because of the action of the torquing spurs.

The heavier base arch wire provides adequate control, and the light torquing auxiliary exerts gentle force for torquing the anterior teeth, the torque force being derived from the resistance of a gingivally directed loop in the main arch between the central incisors.

Figure 7: Heavy arch wire (0.025 in.) with attached 0.016 in. apron-spring torquing auxiliary (from: Begg, 1965: p.91)
A similar auxiliary-main arch combination with spurs only on the central incisors was also illustrated (Begg, 1965: p.92). A further mechanism, suitable for lingual torque of central incisor roots and labial torque of lateral incisor roots was also illustrated. In the latter mechanism, the lateral incisor torquing spurs pointed incisally.

A 0.025 in. diameter base wire was also used in conjunction with the spur-type auxiliary (Figure 8).

![Figure 8: Heavy arch wire (0.025 in.) with 0.0016 in. spur auxiliary; (from: Begg, 1965: p.91)](image)

Begg also illustrated another 0.025 in diameter main arch and 0.016 in or 0.014 in diameter auxiliary combination in which the torquing spur pointed incisally and labially but which provided lingual incisor root torque (Figure 9). This combination has been termed the "reverse rat-trap" appliance.

![Figure 9: Incisally directed apron-spring auxiliary producing lingual root torque. (so-called "reverse rat-trap"). (From Begg, 1965: p.92)](image)
Begg thought that the advantage of the root-torquing auxiliary extending incisally instead of gingivally is that it is much neater and does not occupy such large areas of the labial surfaces of the teeth.

Following the introduction of heavier base arches, several other designs of torquing auxiliaries were advocated; e.g., Kitchton (1967) and Perlow (1973). Both authors recommended that their respective auxiliaries be used in conjunction with a heavy arch wire (0.020 - 0.025 in. diameter) to control the reactive forces produced by activating the distal arms.

Sain (1969) described a series of reciprocal torquing auxiliaries. Combined torque and reverse torque had been previously described by Begg (1965, p.92) but this was in relation to the apron-spring auxiliary type. Sain, however, described a variety of spur-type auxiliaries, for applying various combinations of torque and reverse torque.

The conceptual model (Figure 6 p.31), depicts the work of Kitchton (1967), Perlow (1973) and Sain (1969) as separate developmental trends in the application of torque in the Begg Technique. However the degree of interaction between these trends and the central influence of Begg is illustrated by the fact that, in the second edition of their textbook, Begg and Kesling (1971) include Kitchton and Sain designs in their discussion of torque force application.

At this time, only minor modifications were made to previous recommendations, e.g. the distal arms of the spur auxiliary were curved, to permit them to follow the curve of the main arch around the cuspid area, when the auxiliary was activated (Figure 10). It was also suggested that these arms could be terminated mesial to the canine brackets.

Figure 10: Curved distal arms of spur type torquing auxiliary; (from: Begg and Kesling, 1971: p.133)
Further variations in design of torquing auxiliaries were presented by Begg and Kesling (1977A, pp. 139-140). Like the apron-spring type, these auxiliaries obtained their torque force from contact with a loop in the base arch (see Figures 13 and 14, p. 45).

Not all clinicians, however, followed the recommendation that heavy main arches be used in Stage 3. Brouwer (1973) continued to use an 0.016 in. diameter main arches in conjunction with an 0.016 in. diameter auxiliary, which he described as a 'Brandt type'. Brouwer indicated his preference for this auxiliary, which he considered more effective. Also, because the distal ends were bent up behind the molar tubes in the process of activating the torquing arch, the desired degree of torque force could be accurately determined without removing the arch wire from the teeth.

Brouwer continued to use this auxiliary design, incorporating contraction loops to maintain arch length. His auxiliary, therefore, is depicted in the conceptual model, (p. 31) as a separate developmental trend originating with Brandt's early torquing arch.

4.4 Developments Since 1977

The 1977 third edition of Dr Begg's text, in collaboration with Dr P Kesling, was to be his last. Despite increasingly poor health, he continued to be involved with those who used his technique, even after his retirement from private practice in 1980 (Mollenhauer 1983A). Mollenhauer (1983B) reported that Dr Begg demonstrated a short torquing auxiliary (see Figure 11) at the Australian and New Zealand Begg Lightwire Study Group Meeting at Adelaide in 1981.

Figure 11: 'Short' 4 spur torquing auxiliary
The torquing spurs terminated on the facial surfaces of the lateral incisor crowns, instead of the auxiliary extending distally through the canine brackets.

Fletcher published a text in 1981 which aimed at combining description and review of the Begg appliance. Fletcher acknowledges that "it contains some retrospective judgement, but little comment and even fewer ideas that can be claimed as genuinely original" (Fletcher 1981, preface p.vii).

With specific reference to incisor torquing procedures, Fletcher restates the various auxiliaries in common use, including two and four spur types, omega loop and mousetrap apron spring types as well as various designs for applying combined torque and reverse torque similar to Sain's designs.

However, Fletcher recommended 0.016 in diameter wire for auxiliaries as he found these more stable to handle and less liable to loss of shape or activity. He advocated that auxiliaries extend to the distal of each canine, as "termination distal to the lateral brackets is less assured, but may not be entirely ineffective in cases, with pronounced arch curvature" (Fletcher: 1981, p.43).

Fletcher advocated that a spur angle of 40° be used and be related to the long axis of each tooth, not the plane of the archwire. He thought that spur angle should "not be determined by universal standard regardless of the degree of retroclination of the upper incisors" (Fletcher: 1981, p.42). Figure 12 demonstrates his point:

Figure 12: Spur angle to long axis of tooth is constant (from Fletcher: 1981, p.42)
He explained that keeping the angle of the spurs to the long axes of the teeth as a constant will mean, since tooth angulation varies, that they will subtend varied angles to the archwire horizontal in different cases, but apply the same initial force in all cases.

This approach, of relating spur angle to the degree of retroclination of the teeth to be torqued is a departure from the approaches of previous authors whose recommendations on spur angle were relative to the archwire horizontal.

Kameda's 1982 article raised concerns about the risks of root resorption and the degree of palatal tipping of incisors during Stage 2. He also expressed concern about the length of Stage 3 procedures. He advocated that incisors not be tipped more than 20° past their designated upright positions on basal bone and referred to this concept as "proper tipping". Kameda divided this Stage 2 procedure into 2 phases: the first involving incisor retraction; the second involving mesial molar movement.

Liu and Herschleb (1981) had also discussed the problems of "round tripping" of maxillary incisors and designed a modified force system in which Class I elastic traction and strong anchor bands were used, along with a strengthened anchorage unit, to achieve controlled and efficient movement of maxillary incisors.

Hocevar (1981) had previously examined in some detail, orthodontic force system theory, specifically as it applied to maxillary incisor movements. His 1982 article suggested technical modifications to Begg treatment in the first half of treatment "to include increased concern for controlled movements with intrusion and retraction, with limited tipping" (Hocevar 1982). The main motivation for this was the work of Ten Hoeve, Mulie and Brandt, who ascribed most of the undesirable aspects of 3rd Stage tooth movements to palatal anatomy and injudicious movements of maxillary incisors in the first two stages.

Hocevar considered that a conventional Begg Stage 3 appliance tends to rotate the occlusal plane and especially the maxillary arch down anteriorly and up posteriorly, to deepen the overbite. He suggested several solutions including check elastics and headgear in certain cases (this is dealt with in more detail in section 10.1 p.83).
Mollenhauer (1983B) is a strong advocate of the incisally directed mousetrap mechanism for torquing procedures, which he believes may deliver a more gentle force to the apices of the teeth and is preferable from an oral hygiene point of view. He states that the mousetrap is still the mechanism of choice when the requirement is for different torque for different teeth. He reported excellent results with the relatively new 0.011 Premium Plus Wilcock wire although slightly more activation was needed compared with the 0.012 in diameter wire previously used. He is currently using 0.010 supreme wire for this purpose (Mollenhauer, 1989).

Mollenhauer's 1987 article differentiates between the requirements for cuspid apices to be in the alveolar trough during tooth movement and that requirement to recreate the canine eminence for finishing. He described a simple torquing mechanism for torquing canine roots palatally during Stage 1. He also referred to the fact that occasionally a case may require palatal root torque of cuspid roots in Stage 2 - ie to move apices away from the cortical plate - and illustrates how this can be achieved with a full mousetrap mechanism.

While this literature review is concerned primarily with what some might call "pure Begg", the very fact that the term has usage implies that variations or combinations of Begg principles and other techniques have developed. For the purpose of completeness, a brief mention of these will be made here.

In Graber's and Swain's 1985 text, Thompson's chapter is entitled "Modern Begg: a combination of Begg and straight wire appliances and techniques" (Thompson, 1985). He refers to the development of combination brackets by Chun Hoon (Unitek: 1985, pp.2-10), Fogel and Magill (1963), Kessler (Masel, 1988) and his own 4 Stage appliance (Thompson, 1981).

Such techniques have endeavoured to utilise the advantages of the Begg appliance and minimise perceived disadvantages, particularly in the finishing stages, by utilising the precise finishing capabilities of the edgewise appliance. Thompson's 4 Stage appliance utilises a conventional Begg approach from Stage 1 to Stage 3, including the use of conventional Begg torquing mechanisms to achieve incisor root torque. It is in the 4th stage that the edgewise slot of the bracket is utilised, the preangled, pretorqued and in-out features of the bracket facilitating precise crown and root positioning.
Thompson acknowledges, however, that because human teeth have discrepancies in symmetry, size and function, it is seldom possible to provide ideal occlusal relationships with every final series of straight wire. Final detailing of occlusion may not be optional when torque and angulation are built into the brackets. Consequently, additional adjustments may be needed in the final wires if the best available occlusion is to be achieved.

Thompson's technique has changed further from what was essentially a modified Begg lightwire system (the fourth stage of which was straight wire finishing), to what he calls a Combined Anchorage Technique or CAT system (Thompson 1986, 1988).

The bracket has been modified for efficiency and aesthetics, but the major alteration is the addition of tandem archwires, stabilising archwires, dual-flex archwires and sectional arches, as substitutes for the springs and other auxiliaries in Begg Stage 3 and 4 Stage mechanics.

Torquing is achieved in phase 3 once bite opening and other objectives have been met, using 0.018m diameter steel arches, with tandem nickel titanium arches (either 0.016 in. round or 0.018 in. square or 0.016 in. x 0.022 in. rectangular) in the edgewise slot.

While the 4 Stage appliance could be considered a modification of the Begg appliance, utilising conventional torquing mechanisms, the Combined Anchorage Technique, while utilising a ribbon arch bracket for some of the time, is much more remote from Begg mechanics, particularly in relation to torquing mechanisms.

To summarise this Chapter: the means by which Begg treatment became communicated to the orthodontic world and the role that the orthodontic literature played in this regard has been outlined. A diagramatic representation of the development trends of torquing methods has been presented in an endeavour to illustrate the central influence of Dr Begg in this process and how the interaction of other authors influenced this trend.
The introduction of the use of heavy main arch wires in Stage 3 represented a further step towards providing stability and control of the buccal segments during incisor torquing movements.

Publications since 1977 have been reviewed and finally, mention has been made of the trend by some towards combined techniques, utilising Begg and straight wire principles.
CHAPTER 5

VARIETIES OF BEGG TORQUING AUXILIARIES (Maxillary Incisors)

5.1 Spur Type

5.1.1 Modified Brandt Type

5.1.2 Von der Heydt Type

(a) 0°
(b) 45°

5.1.3 'Shilling' or 'Nickel' Type

(a) Two Spur
(b) Four Spur

5.1.4 Reciprocating Stop Type

(a) Omega Type
(b) Reverse Torquing Type
(c) Modified Spur Type

5.1.5 Sain Reciprocating Torquing Arch

(a) Bilateral Reverse Torque
(b) Unilateral Reverse Torque
(c) 'Z' Unit

5.1.6 O'Meara Individual Tooth Torquing Arches

(a) One spur Type
(b) Two spur Type

5.2 Wing Type

5.2.1 Kitchton Arch

(a) Two Tooth Type
(b) Four Tooth Type
(i) Torque to central and lateral incisors
(ii) Torque to central incisors and reverse torque to lateral incisors
(a) bilateral
(b) unilateral

5.2.2 Perlow Universal Torquing Auxiliary Page

5.3 Apron Spring (Box Spring) type

5.3.1 Rat-trap or Mouse-trap (with gingivally directed apron springs)

(a) Two Tooth Type
(b) Four Tooth Type
(i) Torque to central and lateral incisors
(ii) Torque to central incisors and reverse torque to lateral incisors

5.3.2 'Reverse' Rat-trap (with incisally directed apron springs)
CHAPTER 5

VARIETIES OF BEGG TORQUING AUXILIARIES (Maxillary Incisors)

As indicated in the previous Chapter, methods of torque application in the Begg Technique have varied widely, with respect to design of the torquing arch. Consequently, this Chapter lists the varieties of Begg maxillary incisor torquing auxiliaries that have been used. The list is not intended to be exhaustive, but rather to illustrate variety of design.

Three main types may be delineated:

1. Spur or Loop Types
2. Wing Types
3. Box-Spring or Apron-Spring Types

5.1 SPUR TYPE

5.1.1 Modified 'Brandt' Type

This type, demonstrated by Brouwer (1973; 1974; 1976) is based on the auxiliary used by Brandt (1962). The distal ends of the arch extend through the molar buccal tubes. However, instead of applying torque force to both central and lateral incisors, as Brandt's did, this arch applies central incisor torque only, and instead of molar tie-backs, the arch is cinched back behind the molar tubes. As well as the two torquing loops, Brouwer employed up to three extra vertical loops to keep former extraction spaces closed and to prevent anterior spacing.

5.1.2 von der Heydt Type

This is a commercially available pre-formed arch (Rocky Mountain Orthodontics, 1983), made from 0.014 in. diameter cobalt-nickel alloy and is a two spur design. There are no hooks on the distal ends of the arch as supplied, although von der Heydt outlines a technique of application of his auxiliaries in which the distal 5 mm of each arch end is annealed by the operator and a hook formed for attachment to the main arch (von der Heydt, 1980).
Two arch designs, varying in spur activation are available:

(a) Spurs at 0° to the plane of the auxiliary.
(b) Spurs at 45° to the plane of the auxiliary.

5.1.3 'Shilling' or 'Nickel' Type

This arch design is so-called because its shape and diameter resemble a small coin. Wire diameter is generally 0.014 inch.

(a) Two-spur type: Torque is applied to central incisors only.

(b) Four-spur type:
   (i) Torque is applied to central and lateral incisors.
   (ii) Torque is applied to central incisors and cuspids (Massier, 1977).
   (iii) Asymmetric variations to suit torquing requirements peculiar to a particular case: e.g. torque applied to central and lateral incisors on one side only (Cadman, 1975A).

This auxiliary type may be fashioned by the operator for each particular situation. Preformed arches of varying design and size are also available (e.g. T.P. Laboratories 1987, pp.69-71).

5.1.4 Reciprocating Stop Type

In this type, a vertical spur in the midline of the auxiliary contacts a vertical loop in the main arch, which acts as a reciprocating stop. This is also the principle on which Apron-Spring types, (described in 5.3 p.60) operate.

Spur auxiliaries of this type may vary in design:

(a) Omega Type. This design employs two omega-shaped loops to torque the four incisors, each loop contacting both central and lateral incisors crowns (Figure 13, p.45).
(b) Reverse Torquing Type: This auxiliary design applies labial root torque to lateral incisors only. In this instance, the resistance spur on the main arch wire lies lingual to the vertical midline spur of the auxiliary (Figure 14).

(c) Modified Spur Type: This auxiliary was introduced by Begg in 1965 (Begg, 1965: p.91) and is illustrated in Figure 8, p.34. As well as torquing spurs, there is also a vertical midline spur which contacts the main arch midline loop.

5.1.5 Sain Reciprocal Torquing Arches
This type of arch utilises a combination of torque and reverse torque in spur auxiliaries (Sain, 1969). Various configurations may be used for different applications:

(a) Bilateral Reverse Torque: Torque may be applied to central incisors, with reverse torque to lateral incisors (Sain, 1969; Baldridge, 1973) as illustrated in Figure 15, p.46.
(b) **Unilateral Reverse Torque:** This may be applied by omitting the unwanted distal leg (Sain, 1969), as in Figure 16.

(c) **'Z' Unit:** This simple reciprocal torquing auxiliary is used on adjacent teeth: e.g. mandibular cuspid and bicuspid (Figure 17) or maxillary central and lateral incisors.

5.1.6 **O'Meara Individual Tooth Torquing Auxiliaries**

Developed by Dr. A.J. O'meara, (Blacktown N.S.W., Australia) these arches provide a simple, easily applied means of torquing individual incisor teeth
(O’Meara, 1984, 1986). The designs were first discussed at a Table Clinic as part of the 10th Australian Orthodontic Society Congress at Melbourne, Victoria, in March 1984. Some modification of design has taken place prior to publishing in 1986 (O’Meara, 1986).

(a) One spur type

The vertical arm pictured in Figure 18 is inserted into the bracket slot and the auxiliary activated by engaging the gingival arm.

![Figure 18: O’Meara one spur auxiliary (from: O’Meara, 1984)](image)

(b) Two spur type

This variation is pinned into the bracket slot gingivally to the main arch and the distal arms engaged onto the main arch (Figure 19).

![Figure 19: O’Meara two spur type (from: O’Meara, 1984)](image)
5.2 THE WING TYPE
These torquing auxiliaries contain a central section, or body, and distal arms which, in the passive state, diverge from the body like the wings of a butterfly.

5.2.1 Kitchton Arch
This type consists of a central helical spring from which two arms emerge, ending in hooks. The auxiliary is generally made from 0.016 in. diameter wire (Kitchton, 1967) and may be used for two different applications:

(a) **A two-tooth type** applies lingual torque to central incisors only (Figure 20). Kitchton (1967) regarded this configuration suitable for 95% of cases.

![Figure 20: Two tooth Kitchton arch; (adapted from: Kitchton, 1967).](image)

(b) **A four tooth type** may be used, in which the longer distal arms are curved to allow contact with the lateral incisors, as well as the central incisors.
(i) Torque to central and lateral incisors as illustrated in Figure 21.

Figure 21: Four tooth Kitchton arch; (adapted from: Kitchton, 1987)

(ii) Torque to central incisors and reverse torque to lateral incisors. Several different arrangements may be used:

(a) Bilateral: reverse torque applied to both lateral incisors and lingual torque to central incisors (Figure 22).

(b) Unilateral: reverse torque applied to only one lateral incisor with lingual torque to central incisors (Figure 23, p.50)

Figure 22: Bilateral reverse torque type (Kitchton) (Adapted from: T.F. Laboratories 1984 p.52)
Kitchton emphasised the need to use heavy arches (0.020 in. - 0.025 in.) in conjunction with his auxiliaries, to minimise reactive side effects of torquing movements. An incisal bend in the main arch, distal to the central incisors, was recommended to counteract the extrusive effect on central incisors and the depressive effect on lateral incisors, cuspid and bicuspids.

5.2.2 Perlow Universal Torquing Auxiliary

This auxiliary contains a central hook (instead of a helical coil, as in the Kitchton type), by which it is attached to the main-arch wire. The central section is reinforced by means of a small piece of hollow tubing (0.036 in. diameter) from the end of which, protrude the distal arms.

According to Perlow (1973), the arch may be bent from various wire diameters, from 0.012 in. to 0.018 in., according to the torque force required. Central incisors only, or central and lateral incisors may be torqued, and the auxiliary may be applied to upper or lower incisors, as necessary. Reverse torque may be applied by placing the auxiliary so that the arms lie to the incisal of the main arch wire.

Garcia (1968) had previously described a similar design of wing auxiliary, except that he did not include the tubing reinforcement used by Perlow and he attached his auxiliary to the main arch by means of a tightly bent spiral.
5.3 **APRON-SPRING (BOX-SPRING) TYPE**

Begg claims to have devised these prewound torquing auxiliaries in the late 1950's and refers to them as 'rat-trap' types (Begg and Kesling, 1977A: p.133). However, 'Warren springs', referred to by Bernstein (1971) and 'Muir loops', referred to by Gaudet (1970), are both auxiliaries of similar design to Begg's rat-trap. Gaudet, in fact, refers to Begg's auxiliaries as 'Muir loops', as if, historically, the latter predate the rat-trap. Various designs are used in different situations: The springs are wound around the main arch wire and its midline loop, with the spring usually directed gingivally.

The major advantage of this type of torquing auxiliary is that the teeth may be torqued individually.

5.3.1 **Rat-trap or Mouse-trap with gingivally directed apron springs**

(a) **Two Tooth Type**

Only central incisor teeth are torqued with this auxiliary design, (Figure 24), which was illustrated by Begg (1965, p.91) and by Ford (1968).

![Main arch wire (Adapted from: Ford, 1968)]
(b) Four Tooth Type

This design may be utilised in two ways:

(i) **Torque to central and lateral incisors:** This configuration, illustrated by Begg (1965, p.91) applies lingual root torque to both central and lateral incisors (Figure 7, Chapter 4 p.33). Begg and Kesling (1977A, p.134) also illustrate a similar design, except that in the latter publication, the main arch wire loop, which acts as a reciprocating stop, extends incisally instead of gingivally (Figure 25).

![Figure 25: Main arch wire with attached four spring apron-type auxiliary. Note main arch midline vertical loop extends incisally in this case; (from: Begg and Kesling, 1977A: p.134).](image)

(ii) **Torque to central incisors and reverse torque to lateral incisors:** In this case, the lateral incisor apron-springs extend incisally (Figure 26, p.53) to move the roots of those teeth labially.
5.3.2 "Reverse" Rat-Trap (or Mouse-trap) with incisally directed apron springs

This variation, where lingual root torque is produced by activating an incisally and labially directed apron-spring has been illustrated earlier, in Chapter 4 (Figure 9, p.34). The design currently in use utilises a 'U' spring of 0.014 in. or 0.016 in. wire inserted from the incisal into the central incisor brackets. According to Mollenhauer (1987), this equalises the torquing effects on the two upper central incisors and allows artistic finishing via controlled uprighting, if required.

Mollenhauer (1987) also described a "full" incisally activated mouse trap the apron-spring of which extended all the way to the molars to torque their roots.

While not in wide use, the reverse rat-trap auxiliary has its enthusiastic exponents who believe that it delivers a more gentle force to the apices and also has major oral hygiene benefits, since no mechanism is found gingival to the brackets (Mollenhauer, 1983).
Mollenhauer points out that he is using 0.11 in diameter 'Premium Plus' stainless steel wire (A.J. Wilcock Scientific and Engineering Equipment, Whittlesea, Victoria, Australia) for the open-spring auxiliary in combination with an 0.022 in. diameter special plus Stage 3 main arch. This is in line with recent trends towards the use of very light torque force, thus reducing the need for heavier elastics.

In his 1987 article, Mollenhauer elaborates on the qualities of the 0.011 in. wire which "has been found to be a nice compromise for flexibility, robustness and gentle enough application" (Mollenhauer 1987). He also mentions the use of 0.009 in. diameter wire in the same application.

The late Dr Richard Traill, who formerly practiced in Canberra, Australia, was an enthusiastic user of the 'reverse' rat-trap (Traill, 1982) and he converted his successor to its use also (Fricker, 1987).

This Chapter has been primarily concerned with demonstrating the wide variety in designs of Begg torquing auxiliaries in current use. Auxiliaries may be grouped into three main types. Variations in design within these main groups are employed to suit the torquing requirements of particular situations.
CHAPTER 6

MODE OF ACTION OF BEGG TORQUING AUXILIARIES

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CHAPTER 6

MODE OF ACTION OF BEGG TORQUING AUXILIARIES

Prior to the introduction of light wire torque, the application of torque force had become closely associated with torsion of a square or rectangular arch wire. The various opinions on how light wire torquing auxiliaries deliver torque force will now be considered, in relation to the three main types of Begg auxiliaries previously mentioned in Chapter 5.

6.1 Spur Type

Most of the discussion in the orthodontic literature with respect to mode of action concerns the spur type, probably because this was the first type to be used in the Begg technique. Explanations by Begg himself are vague and seem to be offered as opinions based on experience rather than research.

Begg and Kesling considered that the spur-type auxiliary functions "by working against the anterior curve of the arch wire" (Begg and Kesling, 1977A: p. 133). Begg had also stated, in 1963, as follows:

"The torque force delivered by this auxiliary is derived from the amount of torque in the main line of the auxiliary arch wire" (Begg, 1963).

Begg thus implied that torsion in the wire was the major mechanism. He thought that the spurs play a passive role, acting only as a means of delivery of the torque force from the main line of the arch.

This opinion was opposed by Clouse (1965), whose experiments demonstrating less torque force with longer loops will be discussed later, in Chapter 8, in relation to force magnitude.

However, Fletcher has this to say about the torquing spurs:

"These spurs will transmit the torque forces, but do not generate them and need to be no more than 3 to 4 mm in height. The movement force is derived from the twist, or torque, generated in the horizontal sections of the auxiliary arch wire when the spurs are applied to the labial surfaces of the incisors" (Fletcher, 1981: p.41).
Neuman (1962) presented a formula for calculating the force at the apex of an incisor which was being torqued by a spur auxiliary. His theory of torsion in the wire, however, was not shared by several other authors: Swain (1969A), Clouse (1965) and Neuger (1967) all considered that the method of energy storage and release was not due primarily to torsion of the wire.

Swain (1969, p.709) stated that torque force is subject to the physical principles of a lever. Neuger (1967) thought that the moment producing lingual root torque was mainly the result of bending in the auxiliary, rather than actual torsion along the length of the wire, and therefore, regarded the term 'torquing auxiliary' a misnomer in this sense. His typodont experiments demonstrated that by progressively activating the loops of the auxiliary, the distal ends rotated to approximately the same extent. This observation was confirmed by Scully (1972).

Neuger quoted Thurow's text where the action of a spur type auxiliary is described as:

"the same as that which takes place when a garden hose is twisted as it lies in a curve. The hose will be twisted along its entire length and the end will rotate" (Thurow, 1962)

Neuger concluded from his experiments that while there may be some torsion in a Begg spur auxiliary, most of the forces are stored by bending: that is, compression and tension in the wire.

Scully (1972) explained why the lever action occurs. When the auxiliary is engaged in the central incisor brackets only, with the spurs contacting the labial surfaces of those teeth, the distal arms lie passively, pointing obliquely in an apical direction, illustrated in Figure 27 (p.58). When the distal arms are tied to the main arch, the vertex of the spur is forced against the labial tooth surface producing a lever system, with the active arm being the distal leg of the spur and the distal end of the auxiliary arch.
Figure 27: Mode of action of spur auxiliary; (adapted from: Scully, 1972).

In his typodont experiments, Scully found that no permanent deformation occurred at the bend of the distal leg and in the distal section of the auxiliary. Therefore, he concluded, the system can only act as a lever, with the torque force being generated by bending in the distal leg of the loop and in the distal section of the auxiliary wire.

Scully also observed that the bend between the distal arm of the loop and the distal end of the auxiliary, stood off the surface of the tooth. This, he deduced, could only occur if:

(i) there was torsion in the wire at the vertex of the loop, or
(ii) there was elastic bending distal to the vertex of the loop, or
(iii) a combination of both (i) and (ii) occurred.

He concluded that the last alternative seemed most likely.

Swain (1969A, p.744) distinguished between the torque force applied to central incisors and that applied to lateral incisors. He thought that the auxiliary derives its torque force for central incisors when the distal arms of the auxiliary are hooked onto the main arch wire. However, he thought that the torque force for the lateral incisors is derived partly from the arms and is partly the result of the lateral incisors being located to some degree around the anterior curve of the arch, where, to some extent, they are opposed to one another.
Therefore, Swain considered that the reaction from torque of one lateral incisor creates torque on the other, and vice versa. He used this theory to explain the expansive side effects of lateral incisor torque.

6.2 Wing type

Very little has been written on the mode of action of these torquing auxiliaries, as most investigative studies have concerned the spur type.

Perlow (1973) demonstrated that when his Universal Torquing Auxiliary was stored on a length of arch wire contoured to arch shape, the auxiliary assumed a horizontal position; i.e. with the plane of the body and distal arms parallel to the plane of the main arch wire (Figure 28).

The distal arms in practice, of course, are forced lingually against the labial surfaces of the incisors. This occurs because:

(i) the distal arms are attached around the anterior curve of the arch wire relative to the central hook, and
(ii) the central hook, while closed onto the arch wire to prevent detachment, is free enough to allow the auxiliary to rotate lingually.

![Diagram](image)

Figure 28: The horizontal attitude of a Perlow auxiliary stored on an arch wire, demonstrating mode of action; (adapted from: Perlow 1973).
The Kitchton type of auxiliary (Kitchton, 1967) acts in a similar fashion except that force storage is not only achieved by bending of the resilient lever arms, but also by compression of the central helical torsion spring.

6.3 Apron-Spring Type

This type of auxiliary utilises light wire springs, usually prewound onto a heavy base arch wire which includes a vertical loop or 'V' bend in the midline. According to Begg and Kesling (1977A, p.133), the torque force is obtained from contact of the spring against the midline loop; i.e. the loop acts as a reciprocating stop when the apron-springs are activated against the labial surface of the incisor teeth.

Therefore, torque force is derived from the tendency of the auxiliary to push the main arch stop labially, and not from the attachment of lever arms to the base arch as is the case with other auxiliary types. Swain (1969A, p.744) pointed out that if the loop is deflected labially to any extent by the torquing auxiliary while torquing is being carried out, the main arch will rotate in the brackets proportionally. If there is an anchorage bend in the arch wire, it will rotate outward causing disto-buccal rotation of anchor molars.

This Chapter has dealt with how torquing auxiliaries function. Such a section is a necessary precursor to any discussion of the reactive side-effects of incisor torquing procedures. The three main types of auxiliaries have been dealt with. However, emphasis has been placed on the mode of action of the spur type, as it is with this type, that the present study is concerned.
CHAPTER 7

HISTOLOGIC STUDIES OF TORQUING MOVEMENTS
CHAPTER 7

HISTOLOGIC STUDIES OF TORQUING MOVEMENTS

The relationship of the 'tissue reaction' to the nature and extent of torque force must be considered if optimal tooth movement, with minimal tissue damage, is to be achieved with root torquing procedures. This Chapter considers various histologic studies of root torque, with emphasis on light wire torque, and deals with several investigations which specifically examined the tissue response to Begg torquing mechanics.

Reitan (1985, p.154) states:-

"It is generally assumed that torque movement in a labial or lingual direction essentially causes displacement of the root portion of the tooth, while a fulcrum is established somewhere close to the bracket area".

He points out, however, that it may be shown mechanically, that there is always a tendency for the crown portion to move in the opposite direction. Theoretically, the strongest force will be exerted on opposite sides in the coronal and apical thirds of the root. Despite this, in practice he observed that if a labial arch is tied back to the posterior anchor teeth, there was no perceptible degree of pressure exerted on the opposite side in the marginal region (Reitan, 1985: p.155).

Further to this, Reitan explains that during the initial movement of torque, the pressure area is usually located close to the middle region of the root (Figure 29, p.63), because the periodontal membrane is usually wider in the apical third than in the middle third of the root. Once resorption of bone areas corresponding to the middle third of the root has occurred, the apical surface of the root will gradually begin to compress adjacent periodontal fibres and a wider pressure area will be established.
Neuman (1963) believed that during lingual torquing movements of incisors, the force is distributed over the entire lingual root surface. He reported that the labial surface of the root (the tension side), showed a thickened periodontal membrane and new dense bone being laid down, while on the lingual surface (the pressure side), there was direct bone resorption.

Light wire torque was investigated by Reitan (1964) in humans and in dogs, to determine why teeth may be moved more readily in some cases than in others. He acknowledged that force magnitude was undoubtedly a factor to consider, but he thought that much less is known about the effect of the anatomical environment on the tissue reaction, especially the existing variations in the character of the alveolar bone. Therefore, as well as human tissues, canine material was also examined in his experiments, because of the dense alveolar bone commonly present.

![Figure 29](image)

**Figure 29:** Schematic illustration of lingual root surface pressure areas during torque; 
a: initial pressure area
b: subsequent wider pressure area; 
(adapted from: Reitan, 1965: p.155).

In the human experiments, 0.012 in. diameter apron-springs were used to apply torque force to the upper first premolar teeth. The force, measured at the vertex of the spring was 50 gm. and its duration of application varied from 15 to 30 days for different subjects. In the canine material torque force of between 70 gm. and 200 gm. was applied to maxillary second and third incisors with 0.014 in. diameter apron-springs over periods varying between 15 and 67 days.
Retain found that:

(a) A force of 50 g.m. caused a favourable tissue reaction in the human experiments. Bone resorption was predominantly of the direct type, even after a period as short as 15 days. Minor root resorption lacunae were observable in the middle third of the root but these were repaired by cellular cementum, indicating that the hyalinisation period had been of very short duration. Reitan concluded that the character of the alveolar bone could hardly be more favourable in young orthodontic patients. The exceptions exhibiting a more dense bone type were few.

(b) The canine experiments revealed that the degree of movement depends on the type of alveolar bone more than the duration of force application, and that dense alveolar bone may cause a delay in the resorption process. Bundle bone was resorbed more readily than lamellar bone. Reitan explained that after resorption of the bundle bone, undermining resorption of the dense lamellar bone was delayed by a lack of osteoclasts, which are not found as readily in the relatively dense canine alveolar tissue.

(c) The tissue reaction observed in each case was largely influenced by force magnitude. Forces of between 100 g.m. and 200 g.m. resulted in hyalinisation and root resorption in the middle third and also along the apical third of the root. Reitan found that once started, this resorption would increase in the presence of a strong continuous force. Even the pressure exerted by fibrous tissue against the resorbing root surface would tend to maintain or increase the resorption process.

In contrast to such heavy forces, lighter forces of about 70 g.m. while causing less rapid root movement, produced only minor root resorption in the middle third of the root. This, Reitan considered, is a normal occurrence in bodily movement with continuous forces and such superficial resorption would soon be repaired.
Gaudet (1970), in commenting on Reitan's experiments, pointed out that the forces employed were not purely root torquing forces, since crown tipping as well as root tipping was observed, the crowns moving in the oppositely direction to that of the roots.

In the Begg Technique, however, as Neuman (1963) pointed out, the main arch is cinched back (or tied back) in the molar region. Class II traction prevents the labial tipping of upper incisor crowns, thereby directing the resultant of the torque force to the root surfaces, to accomplish the desired root torque.

Reitan (1964) used dogs in his experiments because he was investigating the effect of bone density on torquing movements. Other investigations of torque force, however, have selected the monkey as their experimental animal: e.g., Huettner and Young (1955), Huettner and Whitman (1958), Gaudet (1970), Ford (1970), Wainwright (1973).

Mills (1955) had pointed out the value of the primate dentition to dental research. This point of view was supported by Gaudet, who selected the monkey because of its closer similarity to humans with respect to the shape, size, position, eruption pattern and attachment of the teeth, compared with other experimental animals.

Huettner and Whitman (1958), utilizing the edgewise mechanism to produce various orthodontic movements in monkeys, applied heavy torque force of up to 9 ounces. They found massive compression with extreme resorption of bone and root on the pressure side. They concluded that "light to moderate forces appear to produce the least amounts of damage" (Huettner and Whitman, 1958). They also found that certain types of orthodontic movements cause more damage than others, tip back bends and torquing procedures producing the greatest damage.

In an interesting experiment on facio-lingual tooth movement in monkeys, Wainwright (1973) torqued premolar teeth through the cortical plate and then back into cancellous bone. He found the following:
(a) As the root apex penetrated the cortical plate, the buccal surface was the only root surface that became devoid of bone. "There was considerable proliferation of cortical plate, which 'followed' the root and maintained the relationship between root and bone on the remaining root surfaces" (Wainwright, 1973).

(b) As the root was moved back and was retained, there was complete repair of the perforation site with further slight thickening of the cortical plate. The force magnitude was measured at the vertex of each spur, with a tension gauge and ranged from 4 ounces to 8 ounces. Duration of the force application varied between 68 days and 89 days.

Gaudet found that the degree of cementum resorptions varied from moderate to severe and that these were more numerous in the teeth subjected to 7 ounces or more of torque force. Only minor cementum resorptions, however, were observed in the teeth subjected to 4 ounces of force.

These finding are in agreement with those of Reitan (1964). Jarabak (1960) thought that 4 ounces of force could be considered the uppermost limit for 'light forces' and for a normal cellular response in bone in the human being.

Ford (1970), in a similar experiment to Gaudet's investigation, used 75 gm. to 90 gm. of torque force over periods varying from 25 days to 50 days. The results indicated osteoclastic activity on the pressure side and osteoblastic activity on the tension side of the alveolar bone. In the 50 day experiment, there was a greater amount of cementum resorption, with some areas of moderate dentine resorption, when compared with the results of the 25 day experiment. In the latter, minor to moderate root resorption was observed, with some resorption areas being contained with cementum.

This Chapter has dealt with histologic research of the tissue reaction to root torquing movements. Animal studies form a large proportion of the work carried out in this area, although some investigation has been carried out utilising human tissues. As far as Begg torquing mechanics is concerned, the animal studies by Gaudet (1970) and Ford (1970) have been considered in the context of histologic research of torquing movements as a whole.
CHAPTER 8

FORCE MAGNITUDE AND SPUR-TYPE TORQUING AUXILIARIES

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CHAPTER 8

FORCE MAGNITUDE AND SPUR-TYPE TORQUING AUXILIARIES

The purpose of this Chapter is to review the orthodontic literature with regard to the magnitude of torque force produced by spur-type torquing auxiliaries. Early concepts of how torque force could be varied, will be briefly reviewed. Then, detailed consideration will be given to studies which have examined force magnitude in relation to the 'nickel arch' torquing auxiliary. Factors which determine force magnitudes produced by this auxiliary type will be reviewed. Finally, consideration will be given to the concepts of optimal and excessive torque force.

8.1 The Early Publications

In Begg's original technique, the torque force applied to the incisor teeth was controlled by the degree of activation of the arch wire vertical root-torquing spurs, and this was varied "to meet the requirements of the case" (Begg, 1956). With the introduction of auxiliary torquing arches in 1961, no further information on force levels was provided, although spur-type auxiliaries with spur angles of approximately 30° to the place of the arch were illustrated.

Brandt (1962) was aware that the torque force exerted by each loop of his auxiliary was influenced by the acuteness of the angle between the spur and the horizontal plane of the auxiliary. He recommended that this angle be made 'deliberately acute'.

Barrer (1963) advocated that the size of the auxiliary be smaller circle than the curvature of the main arch, and recommended a spur angle of 15° to the horizontal plane.

In the first edition of his text (1965) Begg described torquing auxiliaries of various shapes, configurations and wire sizes but no explanation of the ways in which these factors influence force magnitude was offered.
8.2 Studies of Force Magnitude

Several authors have undertaken studies of torque force magnitude and the rate of delivery of such force. Neuman (1963) was concerned with the mathematical calculation of the force at the apex of an incisor, so that the optimal torquing spur angle could be determined.

Others, however, including Clouse (1965), Connelly and Kahler (1967), Neuger (1967), Scully (1972) and Young Yong Kim (1972), developed experimental apparatus to investigate the magnitude of torque force that is produced under various conditions. A more recent study by Leaver and Nikolai (1978) analysed the actual torque values or moments produced by certain auxiliaries, in the context of the entire mechanical system.

Also, as previously mentioned, animal studies were undertaken to determine the histologic response to various levels of torque force other varying periods of application: e.g. Gaudet (1970), Ford (1970).

Neuman's biomechanical analysis of the Begg Technique included a formula for calculating the force exerted in the apical incisal region:

\[
\text{Force} = \frac{\Theta \ G \ r^4}{21d}
\]

where
\(\Theta\) = angle, in radians, which the wire is twisted
\(G\) = average modulus of rigidity for stainless steel
\(r\) = radius of the wire
\(l\) = length of wire
\(d\) = distance from the root apex to bracket area.

He combined "mathematically determined values with clinical results obtained with the aid of cephalometric radiographs and experimentation" (Neuman, 1963). He concluded that the optimal range for the torquing spur angle was "between 45 and 65 degrees in the average case", and that this should be accompanied by a Class II elastic pull of 4 to 5 ounces per side.
In contrast to Neuman's approach, Clouse (1965) investigated the forces produced by torquing auxiliaries using a laboratory model. As reported by Neuger (1967), it was discovered that the length of the torquing loops influenced the amount of force delivered to the root tips: long torque loops delivered less torque force than short loops. According to Swain (1969A, p. 710), Clouse attributed this to the fact that the additional wire length enhances flexibility and therefore decreases the force delivered.

This finding by Clouse is in direct contrast to the opinion expressed in 1963 by Begg, who considered force magnitude to be independent of spur length (Begg, 1963), but gave no evidence to support this view. Previous mention has been made of Fletcher's view that the spurs transmit the torque force but do not generate it (Fletcher, 1961: p.41).

Clouse used two-spur auxiliaries in his experiments. Connelly and Kahler (1967), however tested four-spur torquing arches and reported on the differences between force magnitudes delivered to the central and lateral incisors by the same auxiliary. Young Yong Kim (1972) investigated both two-spur and four-spur designs and found that the two-spur type delivers more torque force to the root tip than the four-spur auxiliary. He thought the additional wire length incorporated into the arch has the effect of decreasing the force delivered.

8.3 **Factors Determining Force Magnitude.**

Neuger's definitive study evaluated the effects of various factors of auxiliary construction and application that affect force magnitude (Neuger, 1967). Scully (1972) carried out a similar series of experiments. Both authors utilised the nickel arch type of auxiliary.

The variables suggested by Neuger were:

1. Type of wire.
2. Diameter of wire.
3. Auxiliary diameter - the size of the circle to which the auxiliary is bent before it is opened and engaged in the brackets.
4. Spur length
5. Spur angle with the plane of the auxiliary at rest.

These factors, Neugler considered, could be varied at will by the operator, but in practice were almost always made the same. He also pointed out that the same auxiliary, placed on two different persons, would probably generate different forces according to such individual characteristics as:

6. Axial inclinations of the teeth.
7. Intercanine distance of the maxillary arch.

8.3.1 Type of Wire

Neugler considered this variable impractical as a means of varying torque force. The use of wire of the same diameter but made of gold spring alloy would undoubtedly reduce force values, but little more would be accomplished than with a stainless steel wire of smaller size.

The use of different alloys of steel with greater stiffness could even produce greater force values. This might not be desirable in terms of optimal force, however, and probably the greater force values might be achieved at the expense of corrosion resistance or increased brittleness.

8.3.2 Diameter of Wire

Neugler thought that force storage in the spur-type torquing auxiliary is mainly by bending (compression and tension) rather than torsion. Stiffness, the chief property of importance in bending, is proportional to the fourth power of the diameter in a round wire. All other things being equal, Neugler found that the torque force produced was proportional to the fourth power of the wire diameter: e.g. an 0.016 in. auxiliary produced forces slightly less than twice those of an 0.014 in. auxiliary. This was confirmed by Scully (1972).
Most authors advocate the use of 0.014 in. diameter wire for spur auxiliaries. Fletcher (1981, p.41) however, recommends the use of 0.016 in. diameter high tensile wire because he considers the resulting auxiliary more stable to handle, being less liable to loss of shape and activity. However, it should be noted that he recommends using 40° of spur activation relative to the long axis of the tooth to reduce the torque force (see Figure 12 p.38).

8.3.3 Auxiliary Arch Diameter

Smaller diameter configurations produced considerably greater force. However, the change in force was not in proportion to the change in diameter. Neuger thought that controlling the circle diameter is an excellent means of altering forces, within limits. If sufficiently accurate measurements could be made, it would be possible to produce an auxiliary with exactly the desired characteristics by combining different wire sizes and circle diameter.

Von de Heydt (1979) advocated the use of shorter auxiliaries in cases where less torque is desired - the auxiliary may be terminated distal to the lateral incisors rather than the cuspids, as is usually the case.

8.3.4 Spur Length

Neuger considered this variable impractical as a means of varying torque force, because the length of the spur is primarily dictated by the amount of exposed crown, gingival to the bracket. He thought that the amount of crown necessary to place a long enough spur for force reduction is often simply not available.

Swain (1969A, p.170), however, advocated using as long a loop as crown height will allow because he thought the longer loop had the additional advantage of reducing the reactionary forces produced by the auxiliary.
8.3.5 **Spur Angle**

Both Neuger and Scully found that auxiliaries with spur angles of $0^\circ$ angulation with the plane of the auxiliary, produced the highest forces at each tooth inclination tested and demonstrated the most consistent forces throughout the test range. Auxiliaries with greater spur angles produced less force which was less constant throughout the test range. This confirmed the opinions of Neuman (1963), Thompson (1972) and Baldrige (1973) who had advocated $45^\circ$ spur angle auxiliaries to reduce the torque force applied.

Fletcher (1981, p.42) advocated a spur angle of $45^\circ$ but related this to the long axis of the tooth rather than the plane of the auxiliary.

8.3.6 **Axial Inclination of the Teeth**

The forces produced by the auxiliaries became progressively less as the roots of the anterior teeth moved lingually (Neuger, 1967; Scully, 1972 and Young Yong Kim, 1972). Neuger found that the force applied to the four anterior teeth is actually shared among them. If any one tooth lags 'behind' the adjacent teeth, the force on that tooth rises and decreases on those that are 'ahead'. This mechanism seems to equalise the axial inclinations of the four anterior teeth.

8.3.7 **Maxillary Intercanine Width**

Neuger found that intercanine distance showed an inverse relationship with the force produced by an auxiliary. He considered this factor as perhaps one of the most important. Translating to the clinical level, patients with smaller dental arches are going to receive the highest forces, exactly opposite to what is desired. He suggested that alterations to auxiliary diameter or wire diameter should be made for these patients so that optimal forces are produced.

In summary: Neuger's study was an excellent in-depth examination of torque force under varying conditions. He concluded that Begg torquing auxiliaries are basically well suited for the task of lingual root movement and that the moments produced are relatively light and consistent throughout their working range.
8.4 Optimal Torque Force/Rate of Torquing

Leaver and Nilolai (1978) evaluated four-spur torquing auxiliaries by means of apparatus which enables separation of the 'torque' from other incisor force systems. They found that, with none of the auxiliary designs tested, was the initial and maximum torque generated above a derived, physiologically acceptable optimal value (4080 grams per millimetre).

It was therefore concluded that the appliance conforms with the light wire-light force nature of the Begg system generally. Leaver and Nikolai also quantified the lingually directed holding forces against the incisors and suggested Class II elastic sizes, in relation to torque magnitude, so as to place incisor centres of rotation at bracket level, or slightly gingival to it.

Reitan (1964), in his experiments of light wire torque on human premolars, showed that 50 gm. is a favourable torque force level. This produced predominantly direct bone resorption, without extensive root resorption. Torque force was applied with an apron-spring which Gaudet (1970) noted delivers force to the tooth in much the same way as does the 'rat-trap' Begg auxiliary.

Brouwer (1973) was in a good position to accurately measure the torque force he applied, because his auxiliary was activated by pulling the distal ends of the arch through the molar tubes and 'cinching back' behind them. Torque force could be measured with a tension gauge and Brouwer aimed to apply 100 gm. of torque force to each central incisor tooth.

Miller (1969), and Barrer and White (1969) thought that the optimal force is in the order of 55 gm. and considered that lingual root movement at the rate of 4° per month indicated an effective application of root torquing force. This force level has also been advocated by Fine (1968).

The Kesling-Rocke Orthodontic Group, in an interview with Dr. S. Brandt (1971) mentioned that on average their rate of torque was about 3° per month. Hurd and Nikolai (1977) found that the duration of Stage 3 and the degree of torque achieved were correlated. However, they advised against indiscriminate use of their figure of 2.6° per month as a standard. They considered the wide variation of torquing rates, as indicated by their high standard deviation figure, rendered the mean rate of 2.6° per month unreliable.
8.5 Excessive Torque Force

Miller (1969) described the effect that excessive torque force would have on mandibular anchorage:

"Excessive torquing forces tend to upset differential force balance and cause a stasis of root movement. The nett effect is a reciprocal labial crown movement, which, in turn, drags the maxillary posterior teeth mesially. Increasing Class II elastics in trying to control this migration of maxillary teeth places excess force on the lower teeth and results in an undesirable forward positioning of these teeth" (Miller, 1969).

Explanation of how anchorage loss occurs with excessive torque force was also given by Neuman (1963) and by Barrer (1963). McDowell (1967), extolling his theory of 'hammock anchorage', considered that excessive torque force would break down the 'hammock' and allow anchorage loss by mesial movement of the anchor molars.

Fine (1969) pointed out that excessive torque force exaggerated the reactive side effects on the buccal segments. He considered that the torquing auxiliary is perhaps the only orthodontic appliance which is placed with the anticipation that it will never have to be adjusted:

"We may be putting in five times the required force and never know it, and in fact may be reducing the torque efficiency and increasing the undesirable side effects" (Fine, 1969).

This Chapter has reviewed those studies which have investigated the magnitude of forces produced by Begg spur-type auxiliaries. Various factors which may determine force magnitude are discussed, within the framework of Neuger's comprehensive study, and opinions of what constitutes 'optimal torque force', and 'optimal rate of torque' are recorded. Finally, the subject of excessive torque force, with the sequelae of anchorage loss and other undesirable side effects are mentioned as a prelude to the following Chapters.
# CHAPTER 9

**ADVERSE STRUCTURAL EFFECTS OF BEGG TORQUING AUXILIARIES**

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CHAPTER 9

ADVERSE STRUCTURAL EFFECTS OF BEGG TORQUING AUXILIARIES

Chapter 9 will consider those adverse side-effects of Begg torquing auxiliaries which relate to changes in the structural integrity of the teeth and gingival tissues. One of these changes, root resorption, has been the subject of considerable interest in relation to Begg treatment, since publications by Edwards (1970) and by Ten Hoeve and Mulie (1976). In this Chapter, root resorption will be discussed specifically in relation to incisor torquing procedures in the Begg technique. Other structural tissue changes, such as pulpal reactions, soft tissue changes and decalcification will also be discussed.

9.1 Root Resorption

Root resorption has been described as "one of the scars of orthodontic treatment" (Jacobson, 1952). It was demonstrated in orthodontically treated patients by Ketcham (1927), and since then, numerous studies have examined root resorption in both treated and untreated cases. Frequency and severity of root resorption are markedly increased by orthodontic treatment and the mechanics used (de Shields, 1969).

Dermaut and de Munck (1988) demonstrated root resorption associated with the intrusion of maxillary incisors. Morse (1971), however, had found that the risk of root resorption seemed to be especially great when root torque is applied.

Venezia (1973) considered the Begg anterior torquing auxiliary to be a highly efficient mechanism, so that in its early application, excessive anterior apical root resorption was created. No evidence was presented, however, to support this view.
Perlow (1968) considered that in the Begg technique, Stage 3 was undoubtedly the most injurious to root and bone. Goldson and Henrikson (1975), however, demonstrated that most of the root resorption occurred during Stages 1 and 2 – the tipping phases, and that the level of resorption increased in frequency and severity during Stage 3 – the torqueing phase. This has been pointed out also by Guy (1970) and by Goldberg (1972).

L'Abée and Sanderink (1985) reported significantly more resorption in Stage 1 than in Stage 2 and that the amount of resorption that occurred in Stage I and III did not differ significantly. They acknowledged that these results differ from earlier published reports, but pointed out that "less torque is being used in treatment nowadays than was formerly the case".

Kameda (1982) reported that root resorption was likely in cases where Stage 2 was lengthy. He thought root resorption, itself, may involve many factors, such as form of the arch wire, strength of orthodontic elastics, and also the patient's age. However, Kameda regarded the degree of lingual tipping of the incisors during Stage 2 as an important factor in root resorption. He stated:

"root resorption is unlikely to occur if tipping is contained within the trough of cancellous alveolar bone."

(Kameda, 1982)

Kameda referred to a study of his in which the intra-oral and cephalometric radiographs of 400 Begg cases were examined. Root resorption of anterior teeth, especially maxillary incisors, was reported where lingual tipping of 25° or 30° had occurred.

Accordingly, Kameda recommended that incisor teeth not be inclined more than 20° past their desired upright positions upon basal bone and referred to this limitation as 'proper tipping'. He also advocated the extraction of second premolars instead of first premolars to reduce the tipping of incisors during Stage 2. Thus Stage 2 was divided into two steps: anterior retraction and posterior protraction. This was done to reduce the likelihood of root resorption.
Some investigations have related root resorption specifically to whether torque was used or not. Goldson and Henrikson (1975) found that root resorption increased more for the upper central incisors, which were subjected to root torque in their study, than for the lateral incisors, which were not.

Ten Hoeve and Mulie (1976), however, criticised Goldson and Henrikson's work, on the basis that the study utilised intra-oral periapical films, pointing out that the amount and nature of resorption that occurred could only be identified in the mesio-distal plane.

Using laminographic techniques, in the labio-lingual plane, Ten Hoeve and Mulie demonstrated a characteristic type of root resorption "extending from the apex of the root, along the lingual root surface, sometimes accompanied by notching and scalloping". (Ten Hoeve and Mulie, 1976). They considered it unlikely that a routine lateral cephalogram would show this type of detail.

The torque force applied in their cases was carefully kept to within a range suggested by Gaudet (1970) and Reitan (1964); i.e. between 70 gms and 120 gms. Ten Hoeve and Mulie considered it unlikely that excessive torque force would account for the root resorption observed. They concluded that:

"there is reason to believe the root resorption may be dependent upon the position of the maxillary incisors and their relation to anatomical structures prior to torquing". (Ten Hoeve and Mulie, 1976).

Therefore, while root resorption has been shown to be associated with root torquing movements in the Begg technique (Goldson and Henrikson, 1971), this resorption may be more associated with the anatomical limitations to torquing movements, referred to by Edwards (1970) and Ten Hoeve and Mulie (1976), than directly with side effects of the torquing auxiliary per se. In the light of this work, Hocevar (1982) concluded:

"it is clear that anatomy of the jaws must be given due consideration in planning the course of treatment and that the objectives of the first half of treatment should be revised to include increased concern for controlled movements of incisors with intrusion and retraction, with limited tipping" (Hocevar, 1982).
9.2 **Pulpal Reactions**

Information on the pulpal effects of torquing movements is extremely limited and no study seems to have been carried out to investigate this aspect of Begg torquing auxiliaries. Unfortunately, neither Gaudet (1970) nor Ford (1970) examined the pulpal tissues as part of their experiments. Therefore, this section deals with the pulpal effects of orthodontic tooth movement in general, and, where applicable, Begg treatment in particular.

Pulpal reaction to orthodontic force had been described by Oppenheim (1942). More recently, Seltzer and Bender (1965) demonstrated radiographically that the orthodontically moved tooth seems to age much faster than the average tooth. There is atrophy of the pulp, eventually leading to early obliteration of the pulp canal by reparative dentine.

Austendig and Kronman (1972) observed the changes in the dental pulp of dog's incisors, which were moved bodily or torqued. Besides the apparent aging of the pulp, the most significant histologic finding was the disruption of the odontoblastic layer. Within the pulpal tissue of the torqued teeth, the disruption was clearly limited to the middle third of the root, but in the bodily moved teeth the disruption extended the length of the root.

The clinical significance of these findings is uncertain. Nor is it clear whether the changes described are transient or reversible. Reitan (1985 p.182) considered it likely that all teeth moved with fixed appliances will undergo certain pulp changes. He distinguished between the small group of teeth which will become devitalised and the other teeth, which in spite of pulp alterations, remain vital.

Devitalisation may occur, according to Reitan, when the pulp structures have become degraded because of the insertion of deep cavity fillings, or by trauma, or severe pressure to the tooth prior to treatment. However, specifically in relation to Begg treatment, Swain and Ackerman (1969) explained that the incidence of devitalisation due to treatment procedures is actually very low, probably because of the relatively low force exerted throughout treatment.
9.3 Gingival Conditions, Decalcification

Kottraba (1971), in a study comparing Begg-treated cases with those treated by means of the Edgewise appliance, reported that there was more gingival hyperplasia during treatment in the Begg case. This returned to normal after the appliance was removed.

Booy (1969) pointed out that the Begg appliance has many focal points for food retention and the presence of torquing loops and uprighting springs render the appliance difficult to clean. This viewpoint was also expressed by Parker (1969), who pointed out the increased possibility of decalcification, due to plaque retention by these auxiliaries including torquing loops. Apron extensions to incisor bands were advocated by Begg and Kesling (1971) and Parker (1969) thought that these extensions may help in reducing decalcification in the region of the spurs of the torquing auxiliary.

Mollenhauer (1983) pointed out that the mousetrap torquing mechanism, where the loops are incisally activated, has a distinct advantage from an oral hygiene point of view, since no mechanism is found gingival to the brackets to retain plaque.

Zachrisson and Zachrisson (1972) demonstrated that, despite adequate plaque removal, most patients develop generalised moderate hyperplastic gingivitis during orthodontic treatment. This subsided after removal of the appliance, a finding also recorded by Kottraba (1970). The latter author, in a comparative study of Begg treatment and cases treated with the Edgewise appliance, found that more gingival hyperplasia occurred in the Begg-treated cases.

In summary: structural side-effects of Begg incisor torquing procedures have been discussed in relation to root resorption, gingival reactions and decalcification. The subject of pulpal reactions has been discussed more generally, however, because of the largely non-specific nature of the orthodontic literature as far as Begg torquing auxiliaries is concerned.
CHAPTER 10

ADVERSE MECHANICAL EFFECTS OF BEGG SPUR-TYPE TORQUING AUXILIARIES

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CHAPTER 10

ADVERSE MECHANICAL EFFECTS OF BEGG SPUR-TYPE TORQUING AUXILIARIES

This Chapter will discuss the various mechanical side-effects of spur-type Begg torquing auxiliaries: i.e. those side-effects which result in changes in tooth position. Changes in the incisor segment, namely, extrusion and spacing, will be mentioned first. Then, the central area of interest to this thesis will be discussed: i.e. the effects of incisor torquing procedures on arch form in the buccal segments.

10.1 Extrusion of Maxillary Incisors

In a cephalometric study of treated cases, Hurd and Nikolai (1977) found that the favourable intrusion of the maxillary incisors experienced during Stages 1 and 2 was generally more than offset by the extrusion which occurs in Stage 3. This confirmed an opinion expressed by Brouwer (1976), based on clinical observation.

Hocevar (1981) reiterated the desirability of bite opening in Stage 1 because of "the substantial potential for extrusion" of the maxillary incisors of a "pure Begg" Stage 3 appliance. He rephrased this in his later article:

"all mechanisms for moving the apices of the upper incisor roots palatally have the side effect of delivering downward force on the anterior teeth and reciprocal upward force on the posterior teeth". (Hocevar, 1982).

According to Leaver and Nikolai (1978), this extrusion tendency was not readily observable intra-orally at the time of activation of the torquing auxiliary. However, it was very prominently displayed in their laboratory apparatus, in which the vertical component of the incisal periodontal support system was absent. Scully (1972) and Young Yong Kim (1972), also observed this extrusion tendency in their respective typodont experiments.
Begg and Kesling (1977A, p.129) recognise that occlusal vectors of force are created by all anterior lingual root torquing auxiliaries, causing increase in overbite. Cadman (1975A) explained that this occurs because the various uprighting and torquing auxiliaries tend to distort the base arch wires. He supported the use of heavier gauge wire for the base arches (0.018 in. or 0.020 in. diameter) introduced by Begg in 1961, stating that these maintained arch form and resisted the distorting action of the auxiliaries.

Swain (1975, p.900) points out that while this tendency towards premature return of overbite is not a problem exclusive to nonextraction treatment, nevertheless it occurs more readily in these cases because of the greater arch length from molar to molar. He emphasizes the importance of using heavy base arches in these cases (0.020 in. and occasionally, 0.022 in. diameter), explaining that the greater flexibility of smaller diameter wires means inadequate resistance against the force of the auxiliaries, with resulting incisor extrusion.

The most commonly reported measure to counteract premature overbite return in Stage 3 is to place slight gingival bends distal to the bracket areas of the maxillary arch wire, as advocated by Begg and Kesling (1977A, p.129). This action has also been recommended by Barbieri and Barbieri (1972), Swain (1975, p.793), Leaver and Nikolai (1978), Cangialosi and Meistrell (1982) and Thompson (1985, p.758).

Cadman (1975A) placed these 'V' bends so that the resultant gingival 'bow' of the main arch wire was level with the gingival margin of the central incisors, when the arch wire was seated in the molar tubes and premolar brackets. He considered the failure to place sufficient gingival bow as a causative factor in increasing overbite in Stage 3. This view is also shared by Swain (1975, p.798) and Begg and Kesling (1977A, p.248).

Hooevar (1982) acknowledged the common use of the 'V' bends but stated that these can actually have an effect opposite to that desired: the combined extrusive effect of the torquing auxiliary and Class II elastics may intrude the molars. He explained that the limits to molar extrusion suggested by McDowell (1967) are reached relatively early in treatment and that continued use of Class II elastics in Stage 3 probably tends to deepen the overbite. He chided those who may attempt to overcome this problem by employing progressively heavier Class II elastics, which he considered, only makes the problem worse.
Three solutions to this problem were suggested by Hocevar to be applied according to the characteristics of each individual case.

(i) In most instances, 'check' elastics are employed in Stage 3 (an elastic which runs from the cinched distal end of the upper arch wire; both strands are hooked under the cinched distal end of the lower arch wire and the end attached to the intermaxillary circle of the upper arch). Hocevar explains that 'check' elastics provide vertical anchorage at the distal ends of both arch wires enhancing the effect of the 'V' band in maintaining overbite reduction.

(ii) High-pull head gear applied to the main arch wire in the incisor region and no Class II elastics is suggested in a case with excessive anterior lower face height and a steep mandibular plane angle. The bite opening is maintained without opening the mandibular plane angle and further increasing lower face height.

(iii) Cervical headgear may be applied in Class II, Division 2 type cases (flat mandibular plane and short anterior lower face height) if extra anchorage in the horizontal plane is required. Besides providing horizontal anchorage, it will hold the posterior portion of the maxillary arch down and possibly open the mandible.

Another reason for increased overbite in Stage 3 is the use of excess torquing force, according to Cadman (1975B), Swain (1975, p.798) and Begg and Kesling (1977A, p.248). To remedy the situation, the latter authors suggest using less activation in the auxiliary or employing an auxiliary constructed from smaller diameter wire. However, as Neuger (1967) demonstrated, these are not the only means available for reducing the amount of torque force applied.
10.2 **Spacing of Maxillary Incisors**

Begg and Kesling (1977A, p.213) have illustrated how spacing may develop during uprighting of lateral incisor and canine teeth. These teeth often require more mesio-distal space after their axial relations have been corrected and some allowance should be made for this, when positioning arch wire intermaxillary hooks. However, there is also a tendency for the torquing auxiliary to cause anterior spacing and this was first mentioned by Begg in 1958 when we described the positioning of the vertical torquing spurs:

"These spurs are preferably placed distally to the brackets, to insure that there will be no creeping apart of the teeth as they are moved. I now make the free ends of these arch spurs to lean over mesially ... so that their force will be delivered to the centres of the teeth" (Begg, 1958).

Spur-type auxiliaries described in later publications (Begg, 1961; 1965; Begg and Kesling, 1971; 1977A) also feature distal placement of the loop relative to the central incisor bracket and a mesial inclination of the torquing loop itself.

However, the commonly used two spur performed cobalt-nickel torquing arches of the von der Heydt design (F-133 and F-334, Rocky Mountain, 1983) are placed with the torquing spurs mesial to the central incisor brackets. Hence, it is usual to ligate the central incisor brackets together to prevent anterior spacing when using these auxiliaries (von der Heydt, 1980). Ford (1968), in conjunction with an apron-spring auxiliary, utilised prewelded eyelets on the mesial of maxillary incisor bands and tied these eyelets together to prevent incisor spacing developing.

Begg and Kesling (1977A, p.137), however, reply on the cinching back of the ends of the arch wire distal to the molar tubes. This prevents the opening of spaces due to the pressures on the teeth from anterior root torquing auxiliaries and uprighting springs. They do not recommend the use of a cuspid ligature tie to the intermaxillary circle. This contrasts with the views of Swain (1975, p.798) and Cadman (1975A) who regarded that failure to use these ligatures routinely usually will result in spacing of the incisors.

Brouwer's modification of the Brandt-type auxiliary (Brouwer 1973; 1974; 1967) incorporated several vertical loops which when activated by cinching the ends of the arch behind the molar tubes, acted to keep spaces closed.
Finally, Swain (1975, p.798) warns against allowing mesial pressure on the hooks of the torquing auxiliary due to impingement by other hooks, ligatures or teeth; this compresses the torque loops and they react as expansion loops.

10.3 Effects on Arch Form

The problem of undesirable reactive effects of incisor torquing movements on posterior arch form was first pointed out by Begg in 1961 (Begg, 1981). Indeed, the very reason for the principal modification to the technique that he introduced later, i.e. the use of auxiliary torquing wires, was to endeavour to prevent the anchor molars moving buccally during torquing and uprighting movements (Begg 1965, p.103).

Previously, when a single arch wire with vertical root-torquing spurs was used, Begg found that the torque force exerted by the spurs transmitted a spiral force along the arch wire, through the anchorage bends to the molar teeth (Begg, 1961). The effect was to move the molars buccally and rotate them disto-buccally.

In the orthodontic literature, these reactive effects of torquing auxiliaries on arch form have been variously described as:

(i) 'flaring' - (Rocke, 1968; Barrer, 1963; 1968; Foster 1968; Kesling, 1968; Barbieri and Barbieri, 1972; Marx, 1989);
(ii) 'expansion' - (Begg, 1965: p. 103; Sims, 1964; Bertrand, 1969; Fine, 1969; Fletcher, 1981);
(iii) 'Molar roll' - (Rocke, 1964; Thompson, 1972).
(iv) 'buccal tipping' - (Cadman 1975, A and B).

In some cases these terms seem to be used interchangeably. Swain (1975, p.942), however, distinguishes between several types of reactive effects in the buccal segments and lists the following: expansion of the buccal segments, buccal tipping, intrusion and disto-buccal rotation. He indicates possible causes of each but points out that frequently all these movements may occur simultaneously. This may account for the different methods of description by various authors.
10.3.1 Intrusion of Maxillary Buccal Segments

Swain (1975, p. 942) considers this to be a direct reaction to anterior torque force. The two-point contact of the auxiliary at the bracket and the labial surface of the crown exerts a root tipping force in one direction and a crown tipping force in the other. This creates a reaction that tends to intrude the teeth at the other end of the arch. In addition, Swain explains, Class II elastic wear augments this intrusive force by restraining forward tipping of maxillary incisor crowns.

Foster (1968) also attributed deleterious changes in the buccal segments to intrusive forces. He explained that such forces are applied at the buccal tube of the molar, which is approximately 6 mm. buccal to the long axis of that tooth, and at the bicuspid bracket approximately 5 mm. buccal to its long axis (Figure 30).

According to Foster, (1968) the effect of these intrusive forces, therefore, is to tend to flare the posterior segments buccally. McDowell (1967) also mentioned the intrusive force on molars; so did Cadman (1975A), who described its effect in terms of buccal tipping of the crowns of the posterior teeth.

![Diagram](image)

**Figure 30:** Effect of intrusive force applied to the molar, at the buccal tube, 6 m.m. buccal to the long axis; (from: Foster, 1968).
As previously mentioned (10.1, p.83) Hocevar (1982) ascribes maxillary molar intrusion in part to the use of 'V' bends distal to canines combined with the extrusive effects of torquing auxiliary and Class II elastics.

Unlike other authors, Swain (1975, p. 943) distinguishes between the reaction to torque force applied to central incisors and that from torquing lateral incisors. He considers that intrusion of maxillary molars, and to some extent bicuspids, is the result of torquing central incisor teeth.

10.3.2 Buccal Expansion

Swain (1975, p. 943) attributes buccal expansion, in part, to the reaction from torque force applied to lateral incisors. His explanation involves consideration of the point of torque force application in relation to the plane of movement of the roots during torquing movements. With central incisors, the plane of application of torque, while located to one side, is close to the plane of rotation of the roots.

However, because the lateral incisors are located partly around the anterior curve of the arch, the attachment of the lever arm for torque is nowhere near the plane of movement taken by the roots.

Swain, therefore, considers lateral incisor torque much less efficient. The roots are moved partly in a posterior direction and partly in a direction toward the midline, with corresponding expansion in the buccal segments as a reaction to this.

Fine (1969) expressed a different point of view. He attributed buccal expansion during Stage 3 mainly to the use of excessive torque force and advocated that cases should be treated in such a way that less torquing movements would be required and hence, less torque force necessary to carry them out. This concept of reducing the amount of root movements necessary in Stage 3 has been expounded by Kameda (1982) and also has been incorporated in the development of several amalgamated treatment techniques which limit free tipping in the early stages of treatment; eg Hocevar (1979; 1982), DeAngelis (1980), Liu and Herschleb (1981) and Thompson (1981; 1985).
The use of light forces has always been a basic tenet of Begg theory and it is in this respect that Fine's viewpoint regarding reducing torque force concurs with that of the 'pure' Begg proponents. Begg and Kesling (1977A, p. 279) emphasise the importance of using light forces to torque anterior teeth so that there would be correspondingly less force exerted at the ends of the auxiliary to intrude the posterior teeth.

10.3.3 Disto-Buccal Rotation of Maxillary Molars

In the early days of the Begg technique, this was caused by transmission of the reaction to torque force to the molars by the anchorage bends in the maxillary arch wire. Even after the introduction of heavy gauge arch wires in 1965, Begg still advocated the use of anchor bends.

However, Rocke (1964) indicated that he was using reduced 'tip-back' bends in Stage 3, and this was reiterated by Kesling (1969). Begg and Kesling (1971, p. 128) stated that only sufficient 'tip-back' should be placed to allow the Stage 3 main arch wire to be passively in the molar tubes.

According to Swain (1975, p. 798) and Cadman (1975A), disto-buccal molar rotation is most often associated with intrusion and buccal expansion. Swain points out that if disto-buccal rotation seems to be occurring alone, it is often the result of the main arch being bent up tightly behind the molar tube, rather than as a direct reaction to torque force. Kesling (1964), however, considered disto-buccal rotation and expansion as part of the same problem.

Begg and Kesling (1977A, p. 217) explained that extra arch length is needed in the anterior segment during torquing and uprighting because of the differences in the mesio-distal width of these teeth when tipped and when uprighted. Often this extra arch length is supplied as the premolars upright, because these teeth require less arch length than when tipped. In cases where the anterior teeth are broad or are excessively tipped at the end of Stage 2, there may be insufficient arch length available in this way. If extraction spaces open up in Stage 3, this would also consume extra arch length.
According to Swain (1975, p. 944) the extra arch length comes from mesial movement of the main arch wire through the molar buccal tube. If the end of the wire is bent up tightly, disto-buccal rotation, expansion or both will occur. The disto-buccal cusps tend to move buccally, with the centres of rotation at the contacts between bicuspid and molars. Secondly, the force is transmitted through the contacts and this causes actual expansion of molars and bicusps.

Swain, therefore, recommends that 2 mm. be left between the end of the tube and the beginning of the arch wire bend to allow for anterior movement of the wire in Stage 3. Marx (1989) also advocated that a space (1 mm) be left between the distal of the molar tube and the cinch bend, to allow for the incisor torquing and canine and premolar root uprighting movements to occur.

Cadman (1975A) thought that only experienced operators should cinch-back the arch wire. A safer method of retaining the arch length without the likelihood of expansion is to ligate the lingual buttons of molar, bicuspid and canine.

The primary purpose of this Chapter has been to review the various reactionary side-effects of incisor torquing movements on tooth positions. Extrusive and spacing tendencies of torquing auxiliaries on maxillary incisors have been reviewed. Buccal segment arch changes have been discussed in terms of three distinct, but closely related, undesirable tooth movements: intrusion, expansion and disto-buccal rotation.
CHAPTER 11

PREVENTION OF BUCCAL SEGMENT ARCH CHANGES DUE TO SPUR-TYPE BEGG TORQUING AUXILIARIES

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CHAPTER 11

PREVENTION OF BUCCAL SEGMENT ARCH CHANGES DUE TO SPUR-TYPE BEGG TORQUING AUXILIARIES

The final Chapter of this Literature Review is concerned with methods of preventing buccal segment arch changes during incisor torquing procedures with Begg spur-type auxiliaries. It has been shown in Chapters 3 and 4 that several modifications made to Begg's technique were directly the result of the need for preventing such changes.

These modifications, namely, the use of auxiliary torquing arches and heavy gauge main arch wires, will be briefly reviewed. Other currently employed method of counteracting buccal arch changes due to torquing auxiliaries will then be discussed.

11.1 Use of Auxiliary Torquing Arch

Begg introduced the use of auxiliary torquing arches to his treatment method in 1961, thereby separating the torquing and supportive functions of the appliance. The simultaneous use of base arch wire and auxiliary torquing wire was an endeavour to prevent the molars from being moved buccally.

In 1965 he reported that this measure had considerably reduced, and in many cases, completely eliminated the flaring out buccally of anchor molars (Begg, 1965: p. 103).

11.2 Use of Heavy Main Arch

In order to completely eliminate the inadvertent buccal movement of molars during torquing, Begg introduced a heavy gauge main arch, 0.025 in. diameter, with light wire root torquing auxiliaries attached. This was done in 1965, after several year's satisfactory trial. The heavy arch, being rigid, resists the force transmitted from the auxiliaries and therefore does not flare out and displace molars buccally. (Begg, 1965: p. 103).
The wire sizes recommended in later years have been slightly smaller: e.g. Begg and Kesling (1971, p. 128) advocated using from 0.020 in. to 0.025 in. diameter wire. In the 1977 edition of their textbook, the wire size recommended is from 0.020 in. to 0.022 in. diameter (Begg and Kesling, 1977A: p. 129). However, the general principle of heavy gauge wires in Stage 3 is well supported by most authors, with only a few exceptions: e.g. Brouwer (1973; 1974; 1976).

Begg and Kesling (1977A, p. 129) considered that the use of an 0.020 in. wire in no way violates the differential force principle, because this heavy round arch wire does not itself perform any tooth movements. Munday (1969) and Cadman (1975A) also emphasise the passive nature of the Stage 3 arch, pointing out that its purpose is to maintain arch form and to resist the distorting action of the auxiliaries.

11.3 Avoidance of Excessive Torque Force

Neumann (1963), Thompson (1972) and Baldrige (1973) all advocated using lower spur angles during torquing in an endeavour to reduce torque force and hence reduce the unwanted side reactions. Cadman (1975B) also considered excessively prolonged torque force accentuated the buccal tipping of maxillary molars in Stage 3.

Fletcher (1981, p.42) felt that "reasonable pressure" should be applied by the torque spurs but warned against using a universally standard spur angulation, regardless of the degree of required retroclination of the incisor teeth. He pointed out that the angulation of incisors will vary from case to case and so the spur angle to be used should be related to the long axis of the tooth, not the plane of the auxiliary and main arch. More enthusiastic pressures may be employed, particularly in more retroclined incisor cases, resulting in a tendency to greater expansion and roll in the buccal segments.
11.4 Main Arch Constriction

Constriction was first employed in the original technique before the use of torquing auxiliaries: "it is the practice to curve the vertically-spurred light arch wire along its distal portion" (Begg, 1965: p. 102). However, Begg went on to report that this measure was not completely effective in preventing buccal arch changes.

Following the introduction of auxiliary torquing arches, constriction of the 0.018 in. main arch used at that time was still employed to offset the buccal flaring. Barrer (1963) and von der Heydt (1965) used main arch configurations which were 'pear-shaped'. Foster (1968), on the other hand, contracted his main arch to such an extent that the distal ends were almost touching when lying passively.

The need for this constricted arch form was reduced when heavier gauge arches were used (Thompson 1972). Munday indicated that an 0.025 in. arch should carry "only the slightest constriction" (Munday, 1969). Begg and Kesling (1971, p. 128) illustrated the degree of constriction necessary in an 0.020 in. diameter main arch wire (Figure 31).

The arch is constricted so that, when lying passively over the occlusal surfaces of the teeth, the distal ends lie approximately midway between the disto-palatal and disto-buccal cusps of the first molars.

![Figure 31: Proper arch form for Stage 3, 0.020 in. maxillary main arch wire; (from: Begg and Kesling, 1977A: p. 129).](image-url)
Ford (1968) more clearly demonstrated that this constriction should begin in the midline (Figure 32). He also warned against placing too much constriction in an 0.020 in. diameter arch wire as this can cause the molars to move palatally.

![Figure 32: 0.020 in. diameter Stage 3 arch wire showing degree of constriction. Note constriction begins in the midline; (from: Ford, 1968).](image)

Cadman (1975A) observed that the amount of constriction necessary is determined not only by the diameter of the wire, but also by the anticipated extent and duration of incisor torque needed. He also illustrated this point by indicating that in treatment of Class II, Division 1 malocclusion, without extraction, less incisor torque is generally required than in extraction treatment. Consequently, less constriction is made in the posterior segments of the maxillary arch wire (Cadman, 1975C).

11.5 **Constriction of Auxiliary Diameter**

Begg and Kesling (1977A, p. 133) recommend that the torquing arch be formed to a smaller circle than the anterior portion of the dental arch. This procedure counteracts the reciprocal forces which are applied to the main arch when the auxiliary is engaged. These forces tend to expand the dental arch.

Two methods of increasing this constriction are mentioned:
(i) the bends at the base of the distal legs can be increased; and
(ii) a slight ‘V’ bend may be placed midway between the spurs.

Both methods cause the distal ends of the auxiliary to come together.

Cadman (1975A) also explained why constriction of the torquing auxiliary is necessary. When the auxiliary is seated in the central incisor brackets, the portions which are to be seated in the lateral incisor and canine brackets are displaced labially, as the loops contact the necks of the central incisors. Cadman thought that the arc of the auxiliary should be shaped so that when it is pinned into the central incisor brackets, the free ends lie gingival to, but neither labial nor lingual to the opening of the lateral incisor and canine bracket slots.

Constriction of torquing auxiliaries, as a means of counteracting side effects to the buccal segments, appears to have been first mentioned by Barrer (1963). Subsequently, von der Heydt (1965) illustrated his torquing auxiliaries which were even more constricted than those described by Barrer. von der Heydt’s auxiliaries were constricted so that the diameter of the circle so formed resembled a small coin.

Begg showed a constricted auxiliary very similar to Von der Heydt’s in his 1965 text (Begg 1965: p.90). Subsequent to this, this method of counteracting reaction forces of torquing auxiliaries was mentioned by Bertrand (1968; 1969) and by Sims (1968) and has now gained general acceptance.

Fletcher (1981, p.42) felt that constriction of the auxiliary diameter was necessary to counteract buccal expansion, but questioned whether contraction of both the main arch and auxiliary would be necessary if the torque force application was modest. We must remember that Fletcher was advocating the use of 0.016 in. diameter auxiliaries.
11.6 Palatal Ligature and Molar 'Cinch-Backs'

Palatal ligation has been advocated mainly as a means of keeping former extraction spaces closed during Stage 3 (Kesling, 1964; Begg, 1965; p. 191). In later years, this procedure has largely been replaced by cinching back the main arch wire distal to the molar tubes (Begg and Kesling, 1977A; p. 137).

However, Thompson (1972) found that if molar-to-canine ties were not used, continuous checks for molar rotations were necessary. He used elastic links instead of soft wire ligatures, to hold the molars from rotating, as well as keeping former extraction spaces closed.

As discussed in Chapter 10, the procedure of cinching the main arch wire behind the molar buccal tubes may produce disto-buccal rotation of molars. This may occur if the arch wire is forceably drawn through the buccal tube as it is cinched back. On the other hand, the cinching-back procedure may be used to actually increase molar control in Stage 3, as described by Begg and Kesling:

"The upper arch wire can be bent so that it rests against the molar band occlusally to the molar tube. This gives increased axial inclination control in the bucco-lingual direction, and helps prevent maxillary molar flaring during Stage 3". (Begg and Kesling, 1977A; p. 137).

Marx (1989) also supported this proposition. He felt that turning the distal end of the arch wire occlusally and then mesially into a fairly hard contact with the buccal surface of the molar on the occlusal side of the tube "reduces the risk of flaring and exerts some buccal torque" (Marx, 1989). He also emphasised the need to take measures to counter molar control problems before they actually happen on the basis that prevention is better than cure.

Begg and Kesling (1977A, p. 137) did recommend using palatal ligature ties if anchor molars show signs of rotating disto-buccally. They pointed out that this procedure is usually required more by beginners, than by experienced orthodontists. The ligature, usually of 0.012 in. diameter wire, passes from the palatal attachment of the molar to the palatal button of the cuspid.
This tie may be twisted with an explorer in the manner of the so-called 'Spanish windlass'. Begg and Kesling pointed out, however, that this should be done, not necessarily to tighten, but to strengthen the tie and make it less susceptible to damage.

Finally, Begg and Kesling recommended that a ligature tie be used from the intermaxillary circle to the cuspid bracket, if molars are being rotated with palatal ligatures. The canine tie will prevent the opening of space anteriorly as the molar rotates back.

In summary: the various methods employed to counteract buccal arch changes have been reviewed. Three of these, namely, the use of auxiliary torquing arches, heavy gauge main arches and constricted torquing auxiliary configurations, have become common procedures in Begg treatment. The role that main arch wire constriction plays in eliminating the reactive effects of torquing has been discussed. Finally, palatal ligation, a procedure that appears to have been largely discarded, is also discussed.
SECTION 2. ORIGINAL WORK

INTRODUCTION

Various authors have recommended that constriction in the horizontal plane of the distal ends of a Begg Stage 3 main arch wire is advisable to counteract any expansion which may occur as a side effect of incisor torquing procedures (Barrer, 1963; von der Heydt, 1985; Begg and Kesling, 1971, p.128).

However, the amount of constriction recommended often appears to be arbitrary, varies from author to author (eg. compare Foster, 1968 with Munday, 1969), and generally appears unrelated to the specific torquing requirements of each case.

The purpose of this study was to devise suitable apparatus and then investigate the relationship between the arch form of a Begg Stage 3 main arch wire and variation in angle of inclination of central incisor teeth being torqued by a spur-type torquing auxiliary.

In this section, the apparatus will be described briefly, with references to Appendices where further description in detail is available. Likewise, archwire materials used will be described briefly also.

Then follows a short description of the measurement method, including diagrams illustrating the areas on the main archwire which were used as points of measurement. A brief description of how the apparatus was improved by successive modifications is also included.

A Pilot experiment, to test the functioning of the apparatus was carried out and the results discussed as a precursor to the main experiments.
### OUTLINE OF RESEARCH DESIGN AND IMPLEMENTATION

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OUTLINE OF RESEARCH DESIGN AND IMPLEMENTATION

1. APPARATUS
Apparatus was developed which enabled measurement of the effects of incisor torquing procedures on the buccal segments of a Stage 3 main arch wire. Movement of the main arch wire was limited by apparatus design to the horizontal plane: i.e. that plane which corresponds to the occlusal plane in vivo.

Detailed explanation and illustration of the apparatus components and the assembly of them is given in Appendix 1, pp. 141 to 155. A brief description of the apparatus is included below.

The apparatus consisted of a perspex and brass frame, (designated the 'frame assembly') into which fitted an 'incisor unit assembly' comprising two plastic typodont teeth with attached Begg brackets (see Figure 33).

![Perspex frame assembly with incisor unit assembly inserted.](image)

These maxillary central incisor teeth were held rigidly together by means of a brass plate with an attached brass rod, one edge of which, was aligned with Begg bracket slots. Into the brackets fitted a prepared main arch and prepared torquing auxiliary.
When inserted into the perspex frame assembly, the incisor unit assembly was supported at the midline of the arch wire by a cradle, in such a manner that the main arch wire lay against two teflon covered microscope glasses which were attached to the under surface of the upper perspex plate (Figure 42-E, Appendix 1.11, p. 143). The movement of the incisor unit rod was restricted to a plane perpendicular to the main arch wire in the midline: i.e. that vertical plane which corresponds to the mid-sagittal plane in vivo.

Therefore, it was possible with this apparatus to vary the activation of a torquing auxiliary (as indicated by the inclination of the incisor unit rod) while restricting the main arch wire to the horizontal plane. Various measurements of the position of the buccal segments of the main arch wire corresponding to a series of inclinations of the incisor unit rod could be made by means of a travelling microscope using low power magnification with background illumination (Figure 34).

By using the focus adjustment of the microscope, it was possible to focus through the transparent upper perspex plate from above, and view the main arch wire. An eyepiece with cross-hairs was used and by manipulating the length and breadth adjustments (see Figure 54, Appendix 1.3, p. 154), the eyepiece could be positioned so that the cross-hairs intersected at chosen positions on the arch wire.

Figure 34: Perspex frame assembly mounted on travelling microscope with illumination source.
2. MATERIALS

2.1 Main Arch Wires

The wires used were performed 0.020 in. diam. stainless steel maxillary arches (special plus grade) supplied by T.P. Laboratories, (La Porte, Indiana, U.S.A., coded 339-46U). The distance between the intermaxillary circles (46mm) and the length of the arch wire itself were chosen after reference to a set of end-of-Stage 2 models on an actual treatment case (Figure 53, Appendix 1.2, p. 153). Each arch wire was standardised by preparing it for length and arch form as described in Appendix 2.1, p. 156.

2.2 Torquing Auxiliaries

The auxiliaries used were two-spur 0.014 in. diam, cobalt-nickel preformed arches (von der Heydt type) supplied by Rocky Mountain Orthodontics (Boulder, Colorado U.S.A., coded F-133). The spur angle of the auxiliary compared to the plane of the main arch was 0°.

These auxiliaries were standardised by preparing them for length and checked for arch form as described in Appendix 2.2, p. 160.

3. MEASUREMENT PROCEDURE

In these experiments, measurements of the position of the buccal segments of the main arch wire were made which corresponded to varying angulations of the incisor teeth being torqued. Because of the apparatus design, this angulation corresponded to the degree of activation of the torquing auxiliary (see Appendix 1.2, pp. 151-153).

It was necessary to choose a standard method of measuring the position of each main arch/torquing auxiliary combination tested. The points on each main arch at which measurements were taken had to be readily accessible to view when the apparatus was assembled and had to be reproducible from one measurement sequence to the next.
The following areas of the main arch wire were used for the purpose of measurement:

3.1 Arch Ends
3.2 Intermaxillary Circles

3.1 Arch Ends.
On either end of the arch, the point used for measurement was the junction between the prepared end of the wire and its buccal surface, as illustrated in Figure 35.

![Diagram of arch end measurement](image)

**Figure 35:** Measurement point at arch end. Circle A represents field of view through Microscope eyepiece. The cross-hairs intersect at the junction of the end of the arch and its buccal surface (Point B).

The ends of the main arch wire were chosen as measurement points because it was expected that any change in width of the arch during activation of the auxiliary would be most pronounced at the ends.

Also, because the arch end is often cinched back around the distal end of the buccal tubes in actual treatment cases, and because reactive effects in the buccal segments are mainly evident in the molar regions, it was considered appropriate to use the arch end as a position for measurement.
3.2 **Intermaxillary Circles**

The intermaxillary circles were chosen as measurement points because they corresponded approximately with the mesial edge of the canine teeth in the treatment case (Figure 59, Appendix 2.1, p. 159). It was considered appropriate to measure any possible circle width changes in the canine regions, although such changes were expected to be much less extensive.

The method used to measure the position of the intermaxillary circles was as follows:

The microscope was manipulated so that the cross-hairs of the eyepiece were positioned tangential to the mesial and buccal outer surfaces respectively, of each intermaxillary circle, as illustrated in Figure 36.

![Diagram of intermaxillary circle measurement](image)

**Figure 36:** Measurement method at an intermaxillary circle. Intersection of cross hairs A is outside circle but in fixed relationship to the radius of the circle, B.

This method of measurement was employed because of the difficulty in finding a reproducible point on the intermaxillary circle which could be used throughout the experiments with an unobstructed view.
3.3 Method

It was necessary to establish a standard method for making the observations and for that purpose, the arch ends were designated the 'near end' and the 'far end' (relative to the position of the observer making the observations). Likewise, the intermaxillary circles were designated the 'near circle' and the 'far circle'.

Figure 37 illustrates these designations and also the labels used to describe the distances between the points on the arch measured, e.g. the distance between the near end and the far end was termed 'end breadth'. The distance between the near end and the near circle was termed the 'near length', etc.

Figure 37: Stylised model of the Stage 3 arch, illustrating the areas measured and the derived distances.

\[ M = \text{midline plane} \]
\[ B = \text{baseline plane} \]
\[ DR = \text{distance between ends (END BREADTH)} \]
\[ DC = \text{distance between circles (CIRCLE BREADTH)} \]
\[ LF = \text{distance between far end and far circle (FAR LENGTH)} \]
\[ LN = \text{distance between near end and near circle (NEAR LENGTH)} \]
The standard method established for taking the measurements for the raw scores is detailed in Appendix 4, p. 170.

It should be noted that 'near length' and 'far length' do not actually represent the arch length between arch ends and intermaxillary circles as such, but are calculated distances derived by subtracting the raw measurement scores of near end and near circle and far end and far circle respectively. Note that the raw measurements are made relative to the zero scale of the length adjustment (see Fig. 54-G, appendix 1.3 p. 154) of the travelling microscope.

4. APPARATUS DEVELOPMENT

Many trials were carried out before the final apparatus design and experimental method were finalised. Originally, the apparatus was operated with the main arch wire contacting the undersurface of the upper plate directly. Friction between arch wire and perspex proved to be a problem as the arch wire did not slide freely.

Various configurations were tried using alternatively Vaseline, oil film and graphite dust as lubricants in an effort to reduce friction between the arch wire and the perspex. The wire slid more freely when microscope cover glasses were attached to the under-surface of the upper perspex plate. Teflon film attached to the perspex directly produced an even better result but the film was difficult to attach to the perspex and still did not eliminate the minute irregularities in the perspex, which interfered with free sliding of the arch wire.

The Teflon film-cover glass combination was found to give the best results. The glass provided a very smooth, unpitted surface and the Teflon reduced the friction between wire and glass.

The manner in which the microscope cover glass/teflon film combination was assembled is described in detail in Appendix 3.1, p. 162.
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PILOT EXPERIMENT

1. AIMS

To test the functioning of the apparatus; to discover any deficiencies in procedure and to test the behaviour of the main arch wire as the torquing auxiliary was activated and deactivated.

2. METHOD

A prepared main arch wire and a prepared torquing auxiliary were attached to the incisor unit (see Appendix 3.2, p. 163). This incisor unit assembly was inserted into the perspex frame assembly with the incisor unit rod positioned on the perspex ledge in the rest position (see Appendix 3.2.2, p. 164).

The torquing auxiliary was activated by moving the incisor unit rod and a series of measurements of the positions of the buccal segments of the main arch wire was taken corresponding to various degrees of activation of the torquing auxiliary, as indicated by the angle of the incisor unit rod relative to the incisor slide scale.

Measurements were taken with the incisor rod at the rest position, then in sequence at 40°, 50°, 60°, 70°, 80°, 90°, 100° and 110° positions. The incisor rod was then returned to the rest position and measurements taken again at this position. This sequence shall be referred to as 'one activation cycle'. The standard method employed is described in Appendix 4, p. 170.

A further two activation cycles were then carried out with measurements being taken only at the end of each cycle i.e. when the incisor unit rod was in the rest position.
3. **RESULTS**

The raw measurements are displayed in Table 1, p.112. Table 2, p.113 lists the derived distances between arch ends (END BREADTH) and between intermaxillary circles (CIRCLE BREADTH). Respective incremental change in these distances, from one angle of activation to the next, are listed in columns 2 and 4.

Table 3, p.114 lists the derived distances NEAR LENGTH and FAR LENGTH and also lists incremental changes in these measurements from one angle of activation of the auxiliary to the next.

4. **DISCUSSION**

(i) As the activation of the torquing auxiliary was increased by moving the incisor unit rod, the width of the main archwire increased. This was the expected result and confirmed the results of previous trials carried out while the apparatus was being developed.

However, it must be emphasised that the experiments were carried out with the movement of the main archwire limited to the horizontal plane, a situation which would not exist in an actual treatment case. A preliminary experiment had indicated that the distal ends of the main arch may move gingivally as well buccally, as the degree of torquing arch activation was increased. However, the present author was not able to devise suitable apparatus which would accurately measure occluso-ungival as well as bucco-palatal changes in arch form under the varying conditions of incisor torque.

(ii) Expansion was more extensive at the arch ends than at the intermaxillary circles. The fact that some expansion does occur at the circles lends support to the advice of Ford (1968) who emphasised the need to begin constriction of a Stage 3 main arch at the midline.
<table>
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<th>NBR</th>
<th>NLR</th>
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<th>FLE</th>
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<td>37.97</td>
<td>24.9</td>
<td>59.63</td>
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</table>

Table 1: Raw measurements for pilot experiment.

\[
\begin{align*}
\text{NBE} & = \text{Near End Breadth} \\
\text{NLE} & = \text{Near End Length} \\
\text{NBR} & = \text{Near Circle Breadth} \\
\text{NLR} & = \text{Near Circle Length} \\
\text{FBE} & = \text{Far End Breadth} \\
\text{FLE} & = \text{Far End Length} \\
\text{FBR} & = \text{Far Circle Breadth} \\
\text{FLR} & = \text{Far Circle Length}
\end{align*}
\]
<table>
<thead>
<tr>
<th>ANGLE (degrees)</th>
<th>Col.1 END BREADTH (NBE minus FBE) (mm)</th>
<th>Col.2 INCREMENTAL CHANGE (mm)</th>
<th>Col.3 CIRCLE BREADTH (NBR minus FBR) (mm)</th>
<th>Col.4 INCREMENTAL CHANGE (mm)</th>
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</table>

Table 2: Changes in END BREADTH and CIRCLE BREADTH for pilot experiment.
<table>
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<th>ANGLE (degrees)</th>
<th>Col.1 FAR LENGTH (FLE minus FLR) (mm)</th>
<th>Col.2 INCREMENTAL CHANGE (mm)</th>
<th>Col.3 NEAR LENGTH (NLE minus NLR) (mm)</th>
<th>Col.4 INCREMENTAL CHANGE (mm)</th>
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<td>-0.10</td>
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<tr>
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<td>70</td>
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<td>-0.08</td>
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Table 3: FAR LENGTH and NEAR LENGTH changes for pilot experiment.
Any expansion at the arch end also produced a relative change in the length of the wire relative to the baseline plane as illustrated in Figure 38.

Figure 38: Change in "Far length" dimension at arch ends as expansion occurs.

- **FE** = Far end
- **FE₁** = Far end after expansion
- **B** = Baseline plane
- **M** = Midline plane

As previously mentioned, it should be noted that the "length" measurements taken (ie, the raw scores) were relative to the zero scale of the microscope table, not the arch wire in the midline of the central incisor region (the baseline plane, B: Figure 38,) and therefore do not represent arch length in the accepted sense. Table 2, p.113, however, shows the changes in length measurements as an increment of the arch wire length in the rest position, for the Pilot Experiment.
The length change accompanying the expansion of arch width may not be clinically significant. This issue is discussed further in the Discussion of the Main Experiments, p. 133.

(iv) Successive activation cycles produced no significant permanent increase in arch width; i.e. the main arch wire behaved elastically during activation of the auxiliary. It was not possible, therefore, to demonstrate the Bauschinger Effect (see Glossary p. 190). This may have been due to the fact that the arch wires were manipulated during their preparation for length and arch form.

It was decided, however, for the purpose of the main experiments to make allowance for any possible Bauschinger Effect in the main arch wire by carrying out a single activation cycle without taking measurements prior to the actual measurement experiments. Further, it was decided to test for any possible Bauschinger Effect in the wire in successive activation cycles by allowing for it in equations proposed to describe the data, as the BLOCK variable. An explanation of the BLOCK variable is given in Appendix 5, p. 173.

(v) Some minor difficulties were experienced with binding of the end of the torquing auxiliary on the Teflon film at the 100° and 110° positions due to a slightly loose ligature. Also, it was found necessary to routinely gently tap the upper perspex plate with a finger at each increment of activation, to ensure that no binding occurred between the main arch wire end and the Teflon film.

(vi) The apparatus was operated according to the standard method described in Appendix 4, p. 170, i.e. over a torquing auxiliary activation range from 0° to 110° (designated the 'FULL RANGE').

However, in vivo, low angles of activation of the auxiliary would be unlikely and, therefore, consideration should be given to a range of activation likely to be of clinical significance (i.e a 'CLINICAL RANGE'). Based on Kameda's recommendation that incisors be limited to tipping within a range of 20° on either side of the vertical, relative to the occlusal plane (Kameda 1982), the activation range of 70° - 110° could be considered a suitable 'clinical range'.
5. CONCLUSIONS

(i) The functioning of the apparatus was tested and changes in the arch form of the main Stage 3 archwire observed for varying degrees of activation of the torquing auxiliary.

(ii) It was decided to accept the limitations of the apparatus and to proceed with the Main Experiment, aimed at quantifying the arch form changes observed in the Pilot Study.

(iii) It was also decided to test the significance of the arch changes that occurred over the 'full range' of activation with those which occurred over the 'clinical range'.

(iv) It was further decided to carry out measurements with the internaxillary circles immobilised, to see what effect this had on the amount of arch expansion in the molar regions. A means of immobilising the circles with bar clips so that the field of view for measurement was not compromised is illustrated in Figures 46 (p. 147) and 47 (p. 148).

(v) Finally, it was decided to incorporate a BLOCK variable to test for any possible Bauschinger Effect in the wire during successive activation cycles.
MAIN EXPERIMENT

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MAIN EXPERIMENT

1. AIMS AND INTRODUCTION

The aim of the main study was to quantify the arch form changes observed in the Pilot Experiment and to test the following hypotheses within the limitations of the laboratory apparatus:

1. Constriction of the main Stage 3 archwire is a reasonable step to take to counteract the expansion that tends to occur as a side effect of incisor torquing procedures.

2. The degree of expansion that occurs compared to the degree of activation of the auxiliary is a linear relationship and, therefore, the amount of constriction of the main Stage 3 archwire should be proportional to the activation of the torquing auxiliary.

3. Expansion of the main Stage 3 archwire occurs not only in the molar regions, but also in the canine regions. Therefore, constriction should be employed from the midline, progressively to the end of the archwire.

4. Disto-buccal flaring of molars during incisor torquing procedures is directly related to the torquing procedure itself.

The designed apparatus allowed comparison between the degree of activation of a 2 spur torquing auxiliary (with this apparatus this was measured by the inclination of the incisor unit rod and designated 'ANGLE') and the arch form of a Stage 3 main arch wire during simulated incisor torquing procedures.
For the purposes of this study, the **DEPENDENT VARIABLES** correspond to the arch wire dimensions illustrated in Figure 37, p.107:

(a) the distance between arch ends ("END BREADTH")

(b) the distance between the intermaxillary circles ("CIRCLE BREADTH")

(c) the distance between the far end and circle ("FAR LENGTH")

(d) the distance between the near end and circle ("NEAR LENGTH")

The **INDEPENDENT VARIABLES** (varying conditions that are expected to change the characteristics of the arch wire form) are:

(a) the angle activation of the torquing auxiliary, as measured by the inclination of the incisor teeth in the apparatus ("ANGLE")

(b) whether or not the intermaxillary circles were immobilised ("CIRCLE TYPE")

(c) the number of times the wire was activated through the full angle range ("BLOCK 1-5") - for explanation of the Block variable, see Appendix 5 pp. 172-173

(d) the actual range over which the wire was activated ("ANGLE RANGE - full vs clinical range")

The relationship between the dependent and independent variables can be simplistically stated as:

<table>
<thead>
<tr>
<th>DEPENDENT VARIABLES</th>
<th>INDEPENDENT VARIABLES</th>
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</thead>
<tbody>
<tr>
<td>END BREADTH</td>
<td>F(ANGLE, CIRCLE TYPE, BLOCK and ANGLE RANGE)</td>
</tr>
<tr>
<td>CIRCLE BREADTH</td>
<td>F(ANGLE, CIRCLE TYPE, BLOCK and ANGLE RANGE)</td>
</tr>
<tr>
<td>FAR LENGTH</td>
<td>F(ANGLE, CIRCLE TYPE, BLOCK and ANGLE RANGE)</td>
</tr>
<tr>
<td>NEAR LENGTH</td>
<td>F(ANGLE, CIRCLE TYPE BLOCK and ANGLE TYPE)</td>
</tr>
</tbody>
</table>

where F = function of (VARIABLE)
It was believed that the data in this study could be described by a linear model or equation. The choice of a linear model was made for two reasons:

1. A cursory look at the data suggested a linear relationship existed (i.e., see scatter plots); and

2. Such models have been shown to be robust in describing even processes known to be non-linear (Koutsoyiannis, 1977, p. 103).

For a detailed explanation of the statistical theory and methods employed, please see Appendix 5, p. 172.

The major questions to be answered in statistical terms by this study are as follows:

1. Do the independent variables influence the dependent variable and, if so, how? This will be assessed by observing the statistical significance and size of the model coefficients and the model F statistic.

2. Does the hypothesised linear relationship between the dependent and independent variables exist? This will be assessed by referring to the model $r^2$ statistic.

3. Can all of the data be used or just that which relates to the clinical range? If the parameters in the equation based on all the data do not differ from those in the equation based on the clinical range of data, then all the data should be used, since this will increase the power of the various statistical tests?

4. Do successive activation cycles produce changes in the arch wire, i.e., those referred to as the Bauschinger Effect (see Appendix 8.1, p. 190) and affect the angle estimate? This will be answered by referring to the statistical significance of the Block estimate?
(5) What difference occurs when the intermaxillary circles are immobilised in the apparatus? This can be determined by comparing the parameters of a model where the circles are fixed with one where they were not?

By answering the questions above in relation to the laboratory experiment, it was hoped to draw clinically relevant conclusions regarding the hypotheses previously stated.

2. METHOD

A prepared main arch wire and a prepared torquing auxiliary were attached to the incisor unit and the Apparatus assembled, as in the Pilot experiment.

A preliminary activation cycle was carried out, without any measurements being taken, to allow for any possible changes in the arch form due to the Bauschinger Effect.

Then, a series of five activation cycles were performed with measurements being taken, as per the standard measurement described in Appendix 4, p. 170. This series of measurements was designated 'CIRCLES FREE' as the intermaxillary circles were not constrained by the brass clips.

A further five activation cycles and accompanying measurements were carried out after the brass clips were applied to immobilise the intermaxillary circles. This series of measurements was designated 'CIRCLES FIXED'.

The raw data was tabulated and 'END BREADTH', 'CIRCLE BREADTH', 'FAR LENGTH' and 'NEAR LENGTH' dimensions calculate. The raw data is presented in Appendix 6, p. 176.

The data was then subjected to the statistical analysis outlined in Appendix 5, p. 172. The linear regression results are presented in Appendix 7, p. 180.
3. RESULTS AND DISCUSSION

Results will be presented and discussed under the following headings:

3.1 CHANGES IN END BREADTH (distance between the arch ends)
   3.1A Full range, circles free
   3.1B Clinical range, circles free
   3.1C Circles fixed

3.2 CHANGES IN CIRCLE BREADTH (distance between intermaxillary circles)
   3.2A Circles free
   3.2B Circles fixed

3.3 CHANGES IN FAR LENGTH (distance between the far end and far circle)
   3.3A Circles free
   3.3B Circles fixed

3.4 CHANGES IN NEAR LENGTH (distance between near end and near circle)
   3.4A Circles free
   3.4B Circles fixed

3.5 FURTHER DISCUSSION AND SUMMARY
3. RESULTS AND DISCUSSION

3.1 CHANGES IN END BREADTH (distance between the arch ends)

The equations relating to the distance between the arch ends are presented in Table 4, p. 126. For explanation of the regression equations, please see Appendix 5, p. 172.

3.1A Full range, circles free

In Table 4, equation 1, the linear model represents a very 'good' fit to the full range of data available, with over 98% of the variation in the dependent variable (BREADTH) having been explained by the independent variable (ANGLE). Figure 39 clearly shows that a strong linear relationship exists.

---

**Figure 39:** Plot of BREADTH vs DEGREES
Arch ends: full range, circles free.

A = 1 observation, B = 2 observations, C = 3 observations, D = 4 observations, E = 5 observations.
3.1B Clinical range, circles free

When only the clinical range of data was used (see Table 4, equation 2, p.126) the model fit and the regression coefficients of the model changed significantly. The model fit is not as good, but still represents a very good fit to the data, with over 93% of the variation in the dependent variable having been explained. Figure 40, shows that a strong linear relationship exists.

Figure 40: Plot of BREADTH vs DEGREES
Arch ends: clinical range, circles free.

A = 1 observation, B = 2 observations, C = 3 observations.

The important difference between the two equations is that the magnitude of the angle coefficient in equation 2 was significantly smaller (i.e. \( b_1 = 0.073 \)). Given this important difference, it was decided that the remaining analysis would only include the data for the clinical range since the use of all the data is likely to give misleading estimates (for explanation of 'clinical range', see p.116, vi).
<table>
<thead>
<tr>
<th>DEPENDENT VARIABLES</th>
<th>INDEPENDENT VARIABLES</th>
<th>COEFFICIENTS</th>
<th>MODEL STATISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIXED</td>
<td>INTERMANDIBULAR CIRCLES</td>
<td>0.004**</td>
<td>R² = 0.6055**</td>
</tr>
<tr>
<td>CLINICAL</td>
<td>ANGLE RANGE</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>0.093**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Angle</td>
<td>0.093**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Block</td>
<td>0.900**</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equation 1:</td>
<td>End Breadth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equation 2:</td>
<td>End Breath</td>
<td></td>
<td></td>
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<tr>
<td>Equation 3:</td>
<td>End Breath</td>
<td></td>
<td></td>
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<tr>
<td>Equation 4:</td>
<td>End Breath</td>
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<td></td>
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<tr>
<td>Equation 5:</td>
<td>End Breath</td>
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</table>
The introduction of the BLOCK variable (see Table 4, equation 3, p.126), showed that it was not statistically significant at the 5% level. It can be said, therefore, that successive activation cycles did not affect the angle estimate and equation 2 was chosen as the most appropriate model for describing the data and can be stated as:

\[ Y = 41.96 + (0.073) \text{ ANGLE} \]

where \( Y \) = predicted distance between the arch ends.

The practical significance of this result is that if, for example, the degree of activation of a torquing auxiliary was 90 degrees, (as would occur in the situation where a zero degree von der Heydt auxiliary was applied to central incisors that were at 90 degrees to the plane of the main archwire), the equation would predict a 1.46mm (ie 0.073 x 20) increase in the distance between the arch ends. Similarly, a 110 degree activation would result in a 2.9mm (ie 0.073 x 40) increase in the distance between the arch ends.

3.1C Circles fixed

Two equations were estimated; one without the BLOCK variable (Table 4, equation 4, p.126) and one including it (Table 4, equation 5). The results showed the BLOCK variable (ie the number of activation cycles) to be insignificant. Therefore equation 4 was chosen as the most appropriate model for describing the data. This equation can be stated as:

\[ Y = 30.72 + (0.049) \text{ ANGLE} \]

This model represented a 'good' fit to the data with over 82% of the variation in the dependent variable having been explained by the independent variable. The most important effect of having the circles fixed was that the angle regression coefficient, although remaining insignificant, became much smaller. For example, a 20 degree increase in angle will result in only a 0.98mm increase in the distance between the arch ends, compared with a 1.46mm increase when the circles were not fixed.
Logically, we should expect that the fixing of the circles would restrict movement in the wire ends in this experimental apparatus situation. However, in vivo, the situation would be much more complex. The canine teeth would not be immobile and any expansive force exerted on them through the brackets may be expressed as orthodontic tooth movement, thus permitting the distal ends of the arch wire to expand to a greater extent than that predicted by the in vitro experiment. The situation would be even more complex than this as the arch wire is attached to lateral incisor and premolar brackets.

It is partly for these reasons that the present experimental apparatus must be seen as a very poor representation of the in vivo situation.

3.2 CHANGES IN CIRCLE BREADTH

The equations relating to the changes in distance between the circles are contained in Table 5, p.129.

3.2A Circles free

Two equations were estimated; one without the BLOCK variable (equation 6) and one including it (equation 7). The results of the regression analysis showed that the number of activation cycles was not a significant factor and therefore equation 6 was chosen as the most appropriate explanatory model. That is:

\[ Y = 40.34 + (0.013) \text{ANGLE}. \]

This model represents a 'good' fit to the data with over 85% of the variation in the dependent variable having been explained. As expected, the angle coefficient (0.013) is much smaller than in any of the previous models since any increase in circle breadth must result in a larger increase in end breadth.
<table>
<thead>
<tr>
<th>Circle Breadth</th>
<th>Equation 6:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle Breath</td>
<td>Equation 7:</td>
</tr>
<tr>
<td>Circle Breath</td>
<td>Equation 8:</td>
</tr>
<tr>
<td>Circle Breath</td>
<td>Equation 9:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model Statistics</th>
<th>Independent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercepts, Angle, Range</td>
<td>Circle Breath</td>
</tr>
<tr>
<td>Block</td>
<td>Circle Breath</td>
</tr>
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<table>
<thead>
<tr>
<th>R²</th>
<th>F</th>
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</thead>
<tbody>
<tr>
<td>0.8577</td>
<td>0.1466</td>
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<td>0.0344</td>
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</tr>
<tr>
<td>0.013</td>
<td>0.010</td>
</tr>
<tr>
<td>0.0004</td>
<td>0.0005</td>
</tr>
<tr>
<td>37.96</td>
<td>0.0004</td>
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</table>

<table>
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<tr>
<th># corrected R²</th>
<th>FIXED</th>
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<tbody>
<tr>
<td>0.1927</td>
<td>0.0004</td>
<td>0.0004</td>
</tr>
<tr>
<td>0.0004</td>
<td>0.0005</td>
<td>37.96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circle Breath</th>
<th>FIXED</th>
<th>CLINICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation 6:</td>
<td>Circle Breath</td>
<td>FIXED</td>
</tr>
<tr>
<td>Equation 7:</td>
<td>Circle Breath</td>
<td>FIXED</td>
</tr>
<tr>
<td>Equation 8:</td>
<td>Circle Breath</td>
<td>FIXED</td>
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</tbody>
</table>

Table 6: Regression Results Relating to the Distance Between the Circle (CIRCLE BREADTH) and the Variables.
The angle coefficient was statistically significant at the 1% level, i.e., a 1 degree increase in the angle will result in a 0.013 mm increase in the distance between the circles. From a practical point of view, the model would predict a 0.26 mm increase (0.013 x 20) in circle breadth where an increase of 20 degrees of torquing arch activation existed.

3.2B Circles fixed

By fixing the internasillary circles, we would expect that the circle breadth also to be fixed regardless of any manipulation of the angle or number of activations.

Two equations were estimated: one without the BLOCK variable (equation 8, Table 5, p.130) and one with the BLOCK variable (equation 9). As expected, the results of the regression analysis showed that both models represented 'poor' fits to the data. In addition, both equations had statistically insignificant coefficients for the angle variable. That is, angle changes did not effect the circle breadth.

However, the BLOCK variable in equation 9 was statistically significant at the 1% level. This suggests that 5 successive activations leads to a 0.1 mm increase in the circle breadth. This result is not clinically significant and could be explained by faulty functioning of the apparatus (e.g., slippage of the brass rods securing the internasillary circles).

3.3 CHANGES IN FAR LENGTH

The equations relating to the changes in the distance between the far end and the far circle are presented in Table 6, p.132.
3.3A Circles free

Two equations were estimated: one without the BLOCK variable (equation 10) and one including it (equation 11). The results of the regression analysis clearly showed that the model including the BLOCK variable provided a better fit to the data, with over 82\% of the variability in the dependent variable having been explained. In addition, the number of activations as represented by the BLOCK variable was statistically significant at the 1\% level. Therefore the most appropriate explanatory model can be stated as:

\[ Y = 22.12 - (0.005) \text{ANGLE} + (0.038) \text{BLOCK} \]

Note, however, that the angle coefficient has not changed from equation 10 and both were statistically significant at the 1\% level. This means that a 40 degree increase in angle could be expected to decrease the distance between the far end and the far circle by 0.2 mm. This effect is independent of the number of activation cycles. The effect of the Block variable on the dependent variable means that after 5 activation cycles, one would expect a 0.019 mm, (ie 0.038 x 5) increase in the distance between the far end and the far circle. This effect is not clinically relevant and could be due to slippage and may also have resulted in the wire becoming asymmetric in its alignment in the apparatus. This indication of slippage will be investigated when the opposite side of the archwire is dealt with (ie changes in the near length).

3.3B Circles fixed

With the circles fixed, one would expect that the previous effects would be somewhat reduced. The regression analysis results support this expectation with both equations having statistically insignificant angle coefficients (see equations 12 and 13, Table 6, p.132.)
Table 6: Regression Results Relative To FAR LENGTH

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<thead>
<tr>
<th></th>
<th></th>
<th>FIXED</th>
<th>CLINICAL</th>
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<tbody>
<tr>
<td></td>
<td>R^2</td>
<td>Block</td>
<td>Intercept</td>
<td>Angle</td>
<td>Intermediately Circles Angle Range</td>
<td>Intermediately Circles Angle Range</td>
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<td></td>
<td>0.3385</td>
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<td>-0.012</td>
<td>0.003</td>
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<td>Far Length</td>
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<td>CLINICAL</td>
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<td></td>
<td>0.6620</td>
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<td>-0.005</td>
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<tr>
<td>Far Length</td>
<td>Equation 2:</td>
<td>FIXED</td>
<td>CLINICAL</td>
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<tr>
<td></td>
<td>16.44</td>
<td>22.2</td>
<td>0.005</td>
<td>-0.005</td>
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</tr>
<tr>
<td>Far Length</td>
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<td>FIXED</td>
<td>CLINICAL</td>
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<td></td>
<td>8.63</td>
<td>22.3</td>
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<td>CLINICAL</td>
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<td></td>
</tr>
</tbody>
</table>

### Model Statistics

- # corrected R^2
- 132
However, the effect of the number of activation cycles, as represented by the Block variable was statistically significant. Again, this may be due to the apparatus failure (i.e., slippage). Note that even this model does not represent a good fit to the data, with only 38% of the variation in the dependent variable having been explained. It is also important to remember that the Block variable is not clinically meaningful and was only entered into the equation in case it had an influence on the Angle variable — it clearly does not.

3.4 CHANGES IN NEAR LENGTH

The results relating to changes in distance between the near end and near circle are presented in Table 7, p.134.

3.4A Circles free

When the Block variable was entered into the model (equation 15) it was shown to be insignificant. Therefore, equation 14 which excluded the block variable was considered to be the most appropriate model. This model did not represent a good fit to the data, with only 15% of the variation in the dependent variable having been explained.

However, the change in angle of activation of the torquing auxiliary was shown to have an impact on the dependent variable, i.e., a 40 degree increase in angle could be expected to decrease the distance between the near end and near circle by 0.44 mm. Note that this effect is twice the size of the effect observed on the opposite side of the archwire. This asymmetry supports the argument that apparatus failure (i.e., slippage) had occurred.

3.4B Circles fixed

With the circles fixed one would expect the previous effects to be somewhat reduced. The regression analysis results confirm this expectation with both equations (16 and 17) showing a reduced effect for
<table>
<thead>
<tr>
<th>#corr R²</th>
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<th>FIXED CLINICAL</th>
<th>FIXED CLINICAL</th>
<th>FIXED CLINICAL</th>
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</thead>
<tbody>
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<tr>
<td>7.995</td>
<td>—</td>
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<td>0.0108</td>
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</table>

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Independent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>Block Angle Intercept Angle Range</td>
</tr>
</tbody>
</table>

**Table 7**: Regression Results Relating to the NRAR Length
angle change and secondly, the number of activations cycles (ie Block variable) having no effect at all on the dependent variable. Given a 40 degree increase in the angle we would predict only a 0.032mm increase in the distance between near end and near circle. Note that the model does not represent a good fit to the data, with only 20% of the variation in the dependent variable having been explained.

FURTHER DISCUSSION AND SUMMARY

Table 8 (p.136) summarises the effect on the various dependent variables of angle change. The estimated effects of a 1 degree, a 20 degree and a 40 degree change in angle on the various dependent variables are listed.

1. For the purpose of this Summary, differences in angle of 20° and 40° have been chosen. This was decided after referring to Kameda (1982), whose concept of "proper tipping" is mentioned on p. 78.

If incisors were not tipped back more than 20° past their ideal root inclinations on basal bone as Kameda suggested, then the results of this laboratory study would predict a 1.46mm change in the distance between the arch ends would need to be compensated for (Table 8, p. 136, [a], circles free, clinical range). Likewise, a 0.26mm change in the distance between the intermaxillary circles would need to be considered also (Table 8, p. 136, [b], circles free).

The possible causes (slippage in the apparatus) for the inconsistencies in the results for Far Length and Near Length have been discussed already. However, the results would predict only between 0.1mm and 0.2mm change in length (Table 8, p. 136, [c], Far Length, circles free and [d] Near Length, circles free). It is unlikely that changes of this magnitude are clinically significant and it is much more likely that causes other than the effect of incisor torquing procedures are responsible for disto-buccal rotation of molars during Stage 3; i.e. excessive anchor bends, excessive and careless cinching back of the distal end of the arch wire etc, as discussed on p. 91.
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Table 8: The Effect of the Various Dependent Variables on Angle Change
In a situation where excessive tipping of incisors occurred prior to Stage 3 (say 40° of torque required) the laboratory study results would predict that arch end expansion of 2.92 mm and intermaxillary circle expansion of 0.52 mm would need to be considered when shaping the main archwire. Between 0.2 mm and 0.4 mm of length change is predicted in this situation also.

The results of this laboratory study support the proposition that expansion of the main archwire occurs as a side effect of incisor torquing procedures. In principle, constriction of the main archwire would seem to be an appropriate step to take to counteract such expansion.

However, whether the laboratory study results can be rigorously applied in the clinical situation is doubtful. The laboratory apparatus used must be considered a poor mechanical representation of the in vivo situation. One of these major limitations is the fact that movement of the main archwire in the apparatus was limited to the horizontal plane (that plane which corresponds to the functional occlusal plane in vivo). In the clinical situation, the main arch would not be limited in this way. Indeed, a crude preliminary experiment carried out during the apparatus development stage showed that the main archwire is likely to move gingivally, as well as buccally during increasing activation of the incisor torquing auxiliary.

In vivo, this would be expressed as gingival as well as buccal force at the molar tube and could result in tipping of the molar as explained by Foster (1968), because such force would be at a distance to the long axis of the molar (see Fig. 30, p. 88).

The further limitations of the laboratory apparatus such as the fact that the attachment of the main arch to lateral incisor, canine and premolar teeth is not taken into account, indicates that valid predictions about the amount of constriction which would be appropriate in a given clinical situation, is not possible.
3. The study results support the hypothesis that for the laboratory apparatus, there was a linear relationship between the degree of torque of the incisor teeth undertaken and the amount of expansion at the arch ends. This supports in principle Cadman's contention (Cadman 1975A) that constriction of the main arch should be determined by the anticipated extent of the incisor torque needed.

Once again, because of the limitations of the existing apparatus, it is not possible to make valid predictions for the clinical situation, but it is possible that a similar linear relationship exists.

4. Expansion of the intermaxillary circles occurred as well as expansion at the arch ends. However, the expansion in the intermaxillary circle region was much less extensive than at the arch ends. This result supports in principle the contention that arch form modification be progressive from the midline around to the molar region, as advocated by Begg and Kesling (1977A, p. 129) and also by Ford (1968).

As previously mentioned, the in vivo situation is far more complex than the laboratory model. The arch would be attached to lateral incisor, canine and one or two premolar teeth and any tendency for the main arch to expand would be expressed as force at the periodontal membrane of these teeth and possibly eventually as orthodontic tooth movement. In the laboratory apparatus, no allowance was made for attachment to these teeth and for any "resistance" to arch expansion which might result. Therefore, the existing apparatus must be considered a poor representation of the in vivo situation.
CONCLUSIONS

1. Constriction of the main archwire as a compensation for buccal segment changes during incisor torquing procedures is a reasonable step, in the experimental apparatus utilised.

2. The postulated linear relationship between the inclination of the incisors being torqued and the buccal archwire expansion was demonstrated and the study results, therefore, support the recommendation that the amount of constriction employed as a compensation should be proportional to the inclination of the incisors to be torqued; i.e. the more retroclined the incisors, proportionally more buccal archwire constriction should be employed.

3. Expansion occurred at the intermaxillary circles, as well as at the arch ends and this finding supports in principle, the practice of progressive arch constriction from the midline to the arch ends.

4. Small changes in the length dimension were observed during the experiments. If similar changes occurred in vivo, it is unlikely that these would be responsible for disto-buccal rotation of molars during incisor torquing procedures. Other factors, such as excessive anchor bends, hard cinching of back of the archwire ends, etc., are more probably causes of this phenomenon.

5. Because of the limitations of the apparatus as a mechanical model, compared with the clinical situation, it is difficult to make precise predictions from the results of this laboratory study which would be valid for clinical practice. For this reason, precise recommendations with respect to the amount of constriction which should be employed for a particular incisor angulation are not justified. A more sophisticated mechanical model would be necessary to enable such valid predictions.
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APPENDIX 1 - APPARATUS DESCRIPTION

The apparatus consisted of several components:

1.1 An assembly of perspex sheet and bars, designated **THE PERSPEX FRAME ASSEMBLY**, which supported the incisor unit assembly mentioned below.

1.2 An **INCISOR UNIT ASSEMBLY** - comprising two plastic typodont incisor teeth with Begg brackets attached to their labial surfaces. A brass rod was fixed to the apical ends of the teeth so that one surface of the rod was aligned with the Begg bracket slots.

1.3 **A TRAVELLING MICROSCOPE** onto the table of which the Perspex Frame Assembly was bolted. The eyepiece of the microscope was used to measure the positions of specific points on each main arch wire tested.

1.4 **A SOURCE OF ILLUMINATION** was necessary to facilitate easy viewing through the microscope eyepiece.

1.1 **PERSPEX FRAME ASSEMBLY**

This consisted of two transparent perspex plates, 4 mm. thick, surmounted by two parallel 6 mm. thick perspex bars. These components were assembled by means of brass tubing, acting as spacers, and brass bolts and nuts. The assembly is illustrated in Figure 33 p. 102.

The major components of the perspex frame assembly were:

1.11 Base Plate.
1.12 Upper Plate.
1.13 Incisor Guide Bars and Scale Slide.
Figure 41: Perspex Frame Assembly
- elevation view.

A. Protractor.
B. Incisor unit guide bar.
C. Upper plate.
D. Base plate.
E. Locking bar.
F. Incisor scale slide.
G. Protractor locking screw.
H. Main arch wire cradle.
I. Rocky Mountain lock
Figure 42: Upper Plate - plan view of undersurface.

A. Central cut out section.
B. Rocky Mountain lock.
C. Main arch wire cradle.
D. Hole to accommodate screw for brass rod to immobilize intermaxillary circles.
E. Teflon covered glass cover slip.
F. Protractor.
G. Protractor adjusting screw.
1.11 **Base Plate**

This 100 mm. x 110 mm. x 4 mm. perspex plate served as a means of attaching the frame assembly rigidly to the microscope table. The 130 mm. x 25 mm. x 3 mm. aluminium locking bar (Figure 41-E, p. 142), was tightened, once the frame assembly was positioned, by means of the 50 mm. x 3 mm. diameter brass screw attached to the base plate.

1.12 **Upper Plate**

This perspex plate served as a means of restricting the movements of the main arch wire to the horizontal plane. The 60 mm. x 20 mm. central section (Figure 42-A, p. 143) had been cut out to permit free movement of the incisor unit assembly and easy insertion and manipulation of it.

To opposite edges of the upper plate were attached two protractors. Each protractor was attached by means of two brass screws, 5 mm. x 1 mm. diameter, which fitted into grooves cut in the protractors (see Figure 43-A, p. 145). After loosening the locking screws, the protractors could be raised or lowered slightly.

Each protractor had a small piece of 0.008 in. diameter wire attached to the 90° axis with cyanoacrylate adhesive so that the wire produced an extension of it: i.e., below the 0 - 180° axis (Figure 43-B, p. 145). This wire extension was used in alignment of the apparatus, as described in Appendix 3.3(ii), p. 168.
Figure 43: Protractor attached to Upper Plate:

A. Locking screw in groove in protractor.
B. Wire extension of 90° axis.

On the undersurface of the upper plate was a lock, (Rocky Mountain, A-224), which was attached by cold cure acrylic resin, at a point 3 mm. from the central cut out section (see Figure 41-I, p. 142). This lock secured the main arch wire cradle bar (Figures 44 and 45, p. 146), the function of which was to support the main arch wire in the midline when the incisor unit assembly was inserted into the apparatus.
Figure 44: Main Arch Wire Cradle Bar
- elevation view.
A. Groove in cradle bar to locate main arch wire
B. Rocky Mountain Lock

Figure 45: Main Arch Wire Cradle Bar
- plan view of undersurface.
A. Rocky Mountain Lock
To the undersurface of the upper perspex plate, on either side of the central cut out section, was attached a piece of microscope cover glass (22 m.m. X 38 m.m., Matsunami Glass, No. 1). Each cover glass, Figure 42-E, p. 143, had a piece of 0.02 mm. teflon film attached to its undersurface. The glass provided a scratch-free surface against which the main arch wire rested. The teflon film served to reduce the friction between the wire and the cover glass.

Adjacent to the cover glass, 8 m.m. from the central cut out section, were two holes in the perspex, 3 m.m. in diameter. (Figure 42-D, p. 143). Tapering brass rods were attached to the undersurface of the upper plate by means of 12 m.m. X 2 m.m. diameter brass screws and the tips of the rods were used to immobilise the intermaxillary circles of the main arch wire in, as illustrated in Figure 46.

Figure 46: Brass rod immobilising intermaxillary circle.
Figure 47: Intermaxillary circle immobilised - cross sectional view.
A. Adjustment screw
B. Upper plate
C. Pivot Screw
D. Microscope cover glass
E. Intermaxillary circle
F. Brass Rod

A small brass screw (6 mm. X 2 mm. diameter) was used as a pivot; when the tip of the brass rod contacted the intermaxillary circle, slight leverage was exerted when the adjustment screw was tightened (see Figure 47).

1.13 Incisor Rod Guide Bar and Scale Slide

These two perspex bars (110 mm X 10 mm X 6 mm.) were mounted 20 mm. above the upper plate to restrict the movement of the incisor unit rod to a plane perpendicular to the main arch wire in the midline. The bars also provided a convenient location for a scale indicating the inclination of the incisor unit rod relative to the plane of the main arch wire. This scale was established using the protractors attached to the upper plate as described in Appendix 3.4, p. 168.
Fitting over the guide bars was the incisor scale slide, which could be moved along the guide bars once the locking screw (Figure 48-A) was loosened. That part of the scale slide which related to the scale itself and against which the incisor unit rod was positioned, was fashioned to a knife edge (Figure 48-C).

![Diagram of Incisor Rod Guide Bars and Scale Slide](image)

**Figure 48:** Incisor Rod Guide Bars and Scale Slide.
A. Locking screw.  
B. Incisor rod guide bar with scale.  
C. Knife edge of scale slide.  
D. Incisor unit rod (in cross-section).

It must be noted that the scale slide was not used to measure various positions of the knife-edge relative to the scale. Rather, its purpose was to provide a means of accurately positioning the rod of the incisor unit assembly to a series of predetermined angulations. The slide was moved until the knife edge indicated a required angulation determined from the scale and then the slide was locked in position. The incisor unit rod was then moved until its leading edge contacted the knife edge of the scale slide, as illustrated in Figure 49 p. 150.
Figure 49: Plan view of Apparatus illustrating Scale Slide.

Incisor unit rod (A) contacts knife edge of scale (B) slide which is locked at the 50° position.

Several pieces of 4 mm thick perspex, glued together, were attached to the undersurface of that guide bar on which was inscribed the incisor scale. They served as an extension of the guide bar in the vertical plane when the incisor unit rod was being manipulated from the rest position to the 40° position. A horizontal shelf, Figure 50-A level with the upper perspex plate of the frame assembly served as a convenient means of supporting the incisor unit rod in the rest position.

Figure 50(a): Schematic view in elevation illustrating perspex extension to upper plate (shaded area A.) B. Upper plate; C. Incisor Unit rod.
1.2 INCISOR UNIT

This consisted of two plastic typodont maxillary central incisor teeth, connected to each other by means of a brass plate which fitted over the ends of the root portions (Figure 51). The roots were held rigidly to the brass plate by two small brass screws.
**Figure 52:** Incisor Unit, elevation view.

This illustrates the alignment of upper edge of incisor rod A with Begg bracket slot, compared with long axis of incisor teeth, B.

A 4 m.m. diameter brass rod, designated as the 'incisor unit rod', protruded from the brass plate which had been machined in such a manner that the upper surface of the rod was aligned with the bracket slots of Begg brackets attached to the labial surfaces of the teeth (See Figure 52).

The incisor unit was constructed in the following manner:

Begg brackets (Rocky Mountain A1089 on D2220 bases) were attached to the labial surfaces of two typodont teeth using an acrylic adhesive (Monoloc, Rocky Mountain Orthodontics, Inc.). An 0.020 in. diameter preformed Stage 3 maxillary arch wire (T.P. Laboratories, Inc.), prepared as described in appendix 2.1, p. 156, was pinned into each bracket slot, using Stage 3 lock pins. Cyanoacrylate adhesive was used to temporarily attach together the mesial surfaces of the crowns of the typodont teeth.

The study models, at the end of Stage 2 of an active treatment case (Figure 53, p. 153) were used as a guide to arch form and incisor inclination. The root portions of the typodont teeth were stabilised using a small piece of wire and cold cure acrylic resin: when this resin had polymerised, acrylic was also added to the junction of the mesial surfaces of the crowns.

The incisor unit rod and the brass plate were assembled and, by a process of trial and error, the root-fitting surface of the plate was machined until the leading edge of the incisor unit rod was aligned with the bracket slots of the Begg brackets (see Figure 52). Holes were drilled through the brass plate into the root portions of the teeth to accept brass screws. The screws were inserted and the plate and teeth locked firmly together.
Finally, the assembly was checked again to see that the leading edge of the rod and bracket slots were aligned.

The arch wire was unpinned and discarded. Its purpose was to ensure that experimental wires could be inserted and pinned in place with minimum stress on the brackets and without altering the dimensions of the arch form.

1.3 TRAVELLING MICROSCOPE

The Beck Travelling microscope (Figure 54, p. 154) was used as a means of viewing and measuring, in two planes, the position of the main arch wire under different conditions of torque of the incisor teeth.

For the purposes of clear description it has been necessary to label the various adjustment knobs and measurement scales (see Figure 54, p. 154).

The adjustment knob (H) moves the microscope eyepiece parallel to the long axis of the table indicated by the broken line C; this axis has been designated the length axis and the adjustment knob (H) and the corresponding measurement scale (G) are designated the length adjustment and length scale respectively.
Figure 54: Beck Travelling Microscope.
A. Breadth axis.
B. Focus adjustment knob.
C. Length axis.
D. Table.
E. Breadth adjustment.
F. Breadth scale.
G. Length scale.
H. Length adjustment.
The adjustment knob (B) moves the microscope eyepiece perpendicular to the length axis in the direction of the broken line (A). This axis has been designated the breadth axis and the adjustment knob (E) and the corresponding vernier scale (F) are designated the breadth adjustment and breadth scale respectively.

The focus adjustment knob (B) provided a means of focusing through the perspex plate onto the main arch wire itself. Low power magnification (6 X) with a cross-hair eyepiece was used with low intensity illumination.

1.4 SOURCE OF ILLUMINATION

The light source used was an Olympus incident light illuminator (Figure 50) with the field diaphragm opened to maximum. Low power illumination was used, the light source being located at the rear of the microscope and directed obliquely downwards towards the viewing table (See Figure 34, p. 103). The resulting illumination was diffuse, much of the light being reflected from the white laminate bench top on which the experiments were conducted. This arrangement proved to be ideal for the purposes of the experiments.

Figure 55: Olympus Incident Light Illuminator with Voltage Regulator.
APPENDIX 2 - MATERIALS PREPARATION

The following materials required preparation:

2.1 Main Arch Wires
2.2 Torquing Auxiliaries

2.1 Main Arch Wires

The wires used were preformed 0.020" diameter Stage 3 arches ("special plus") supplied by T.P. Laboratories, Inc. (see Figure 56).

![Figure 56: Unmodified Main Arch and Torquing Auxiliary (as supplied).](image)

The intermaxillary ring distance of 46 mm had been chosen after referring to the maxillary cast at the end of Stage 2 of an actual treatment case (see Figure 59, p. 159).

Each arch wire was prepared in the following manner:

(i) The arch wire identification label was removed with a razor blade.

(ii) The gable bends distal to the intermaxillary circles were eliminated using Ash 64 pliers. This was done to ensure that the distal ends of the arch lay in the same plane as the anterior portion.
(iii) Similarly, the gingival curve of the anterior portion of the arch wire was also removed.

(iv) The arch was then placed on a flat surface with the intermaxillary circles uppermost and was checked to ensure that both anterior and posterior portions of the wire lay in the same plane (Figure 57).

![Figure 57: Main arch on a flat surface](image)

(v) The arch wire was then placed on a millimeter grid with the maxillary circles uppermost, to check for arch symmetry and also to adjust the length of the distal segments.

(a) The anterior portion of the wire was placed at a tangent to the horizontal axis of the grid and the intermaxillary circles were positioned so that their outer surfaces were equidistant from the vertical axis of the grid (See Figure 58).

![Figure 58: Modified main arch on grid to check for length and symmetry.](image)
(b) Quickly drying white typewriter correction fluid was then applied to the wire in the midline. Similar marks were also placed on the distal segments at points 30 mm. from the horizontal axis of the grid. This length had been previously determined by trial and error, by fitting wires to the maxillary model of the treatment case previously mentioned, to represent the arch length from the midline to the end of the buccal tube on each side.

(c) Using a sharp razor blade, all three correction fluid marks were trimmed to as small an area as possible. The dried fluid was easily trimmed and the remaining fluid continued to adhere to the wire. Previous attempts with a white wax pencil proved unsatisfactory as the marks were not easily trimmed, without dislodging the remaining part of the mark on the wire.

(d) The arch was removed from the grid and, using the fluid marks as guides, the distal ends of the wire were cut using a slowly rotating carborundum disc in a straight handpiece. This was done with the disc rotating away from the buccal surface of the wire to avoid burring of this surface, because it was intended to use the junction of the buccal surface and the arch end as a point of measurement in the experiments.

(e) The arch wire was then returned to the grid and aligned using the midline mark and the intermaxillary circles. The length to which the distal ends of the wire had been trimmed was then checked to be 30 mm. Where further adjustment in length was required, (d) was repeated.
The arch was then checked for symmetry. Where necessary, the molar offsets were adjusted slightly to ensure that the buccal surface of each arch end was 20 mm. from the vertical axis of the grid. It had been previously determined using the maxillary cast of the treatment case, that this was the distance between the arch ends at rest, which would place them across the central fossae of the maxillary first molars (Figure 54) as recommended by Begg (Begg and Kesling, 1971, p.129).

![Image of prepared main arch wire on end of Stage 2 cast]

Figure 59: Prepared main arch wire on end of Stage 2 cast

Small bends of about 5° away from the flat surface of the arch were placed at the molar offsets. This was done to ensure that when torquing arch was activated and the main arch wire forced against the teflon film coated glass cover slip, that it was the rounded bend of the molar offset and not the sharp arch end which contacted the teflon.

The arch wire was finally returned to the millimeter grid, aligned using the midline mark and intermaxillary rings, and then checked once more for symmetry with respect to length of the ends and width between them. Any arches which did not comply were discarded. Acceptable arches were stored for future use.
2.2 TORQUING AUXILIARIES

The torquing auxiliaries used were preformed 0.014 in. diameter cobalt-nickel arches of the Von der Heydt type, with a spur angle of 0° (F-133, Rocky Mountain Orthodontics, Inc.).

Each torquing auxiliary was prepared in the following manner:

(i) The auxiliary was placed on the millimeter grid so that the inter-bracket area was at a tangent to the horizontal axis of the grid, and so that the mesial arms of the torquing spurs were equidistant from the vertical axis (Figure 60).

(ii) Using white typewriter correction fluid, marks were placed on the wire in the midline and on each distal arm 15 mm. from the horizontal axis. This length had been previously determined to be sufficient to permit easy ligation to the intermaxillary circle, as described in Appendix 3.2.1, (ii) p. 163, but not so long as to allow contact of the ends of the torque arch with the teflon film when the torque arch was activated.

(iii) A sharp razor blade was used to trim the set typewriter fluid marks to small areas.

(iv) Using the marks on the distal arms as guides, a slowly rotating carborundum disc in a straight handpiece was used to cut the ends at the desired length, this length was checked by returning the auxiliary to the grid.

Figure 60: Modified torquing auxiliary on grid.
(v) Each modified arch was returned to the grid for checking (Figure 60, p. 160).

Any auxiliary which was obviously asymmetrical was discarded. No attempt was made to alter the shape of auxiliaries because of the heat-treated nature of the wire. Acceptable arches were stored for future use.
APPENDIX 3 - APPARATUS PREPARATION

3.1  Cover Glass/Teflon Film Preparation
3.2  Incisor Unit Assembly

3.2.1  Preparation
3.2.2  Insertion into Frame Assembly

3.3  Positioning of Protractors and Incisor Unit Cradle
3.4  Establishment of the Incisor Scale

3.1  COVER GLASS/TEFLON FILM PREPARATION

The cover glass pieces, attached to the undersurface of the upper perspex plate of the frame assembly and their teflon film coverings were prepared in the following manner:

(i) Several layers of teflon film 0.02 mm. (Glad Freezer Wrap) was taped flat onto a cardboard surface. Using a scalpel and a steel cutting edge, rectangles of film were cut 21.5 mm. x 37.5 mm., i.e. slightly smaller than the dimensions of the pieces of cover glass. Those teflon film pieces not for immediate use were stored between film.

(ii) Two cover glass pieces to be used were coated with a thin layer of silicone using a fine pressure pack spray (P.R. Silicone pressure pack spray - Rocol/Lubricants, Alexandria, N.S.W.). By handling the teflon film with dressing tweezers, a piece of film was applied to the silicone-coated surface of each cover glass by rolling it on from one end to the other to exclude air bubbles. By using a piece of teflon film as a glove, finger pressure was used from the centre of the cover glass outwards to smooth out any minute air bubbles. The rectangle of teflon film was finally centered on the cover glass.
The frame assembly was dismantled and the undersurface of the upper perspex plate cleaned of any dust or grease with ethyl alcohol. Each teflon film coated cover glass was applied to the undersurface of the upper plate using minute smears of cyanoacrylate adhesive in each corner and finger pressure in a teflon "glove" used to position each cover glass correctly. After each experiment, cover glasses were easily removed by breaking the tiny cyanoacrylate adhesions with a scalpel.

3.2 **INCISOR UNIT ASSEMBLY**

3.2.1 **Preparation**

Prepared main arch wires and prepared torquing auxiliaries were attached to the incisor unit in the following manner:

(i) Both main arch and auxiliary were pinned into the brackets of the incisor unit using Stage 3 lock pins (207 - 341, T.P. Laboratories, Inc.) so that the correcting fluid marks in the midline of each arch corresponded to each other. The torquing auxiliary was placed gingival to the main arch as is usual in vivo.

(ii) Using 0.008 in. diameter soft ligature wire, the arches were ligated together midway between incisor brackets and intermaxillary circles on either side. These ties corresponded to the ligature ties placed at the lateral incisor brackets in vivo. Each ligature was tied using fine-beaked artery forceps. It was found that if the beaks were positioned about 3 mm. from the arch wires that the ligature, when tightened by twisting, would fracture close to the arch wires leaving a very tight ligature wire with little tag end.

(iii) Ligatures were also placed at each intermaxillary circle in such a manner that the ligatures would not foul the teflon film when the intermaxillary circles lay against it during the experiments. It was possible to do this by tying the ligatures in a figure-of-eight fashion between mesial and distal aspects of each intermaxillary circle (See Figure 61-A, p. 164).
3.2.2 Insertion into the Frame Assembly

(i) The assembled incisor unit was carefully inserted into the frame assembly, so that the teflon films covering the cover glasses were not disturbed.

(ii) The main archwire was fitted into the incisor support cradle, with the midline mark midway between the supporting arms of the cradle. The incisor unit rod was positioned on the perspex table in the rest position.

(iii) An 0.014 in. diameter stainless steel wire, fashioned into a small hook at one end, was passed through a small access hole in the frame assembly and the hook attached to the main arch, midway between the incisor teeth. The hook was small enough to avoid contact with the torquing auxiliary (Figure 61-C).

(iv) The other end of the wire was attached to a bucket containing 200gm of lead shot (Figure 62, p. 165).

The purpose of the wire was to stabilise the incisor unit assembly in the cradle during the activation procedures.
Figure 62: Assembled apparatus.  
A. Stabilising Wire.  
B. Shot Basket.

The main arch wire was positioned so that it was supported in the midline by the main arch wire cradle bar. The incisor unit rod was placed on the perspex shelf in the rest or unactivated position (see Figures 44 and 45, p. 146).

3.3 POSITIONING OF PROTRACTORS AND INCISOR UNIT CRADLE

These procedures were carried out with trial arch wires placed in the incisor unit using the procedures described in Appendix 3.2.2.

(i) The incisor unit assembly was inserted in the frame with the main arch contacting the undersurface of the upper perspex plate. The stabilising wire was attached to the main arch in the midline, by its hook and with the incisor rod horizontal, the unit was positioned so that the arms of the incisor cradle supported the main arch wire in the midline. The shot bucket was attached to the stabilising wire to immobilise the incisor unit assembly on the cradle.
(ii) The lock securing the incisor cradle rod was loosened via an access hole in the base of the frame assembly. The incisor cradle rod was then positioned in the horizontal plane so that the main arch wire, on the cradle, lay exactly in line with the vertical axes of both protractors (See Figure 63.)

This positioning was done endeavouring to avoid parallax error. The wire extensions of the vertical axis of each protractor greatly facilitated this procedure. Once correctly positioned, the cradle rod was immobilised by tightening the lock and alignment was checked again.

---

**Figure 63:** Alignment of Incisor Unit Cradle with vertical axis of each protractor.

**Figure 64:** Alignment of horizontal axes of each protractor with Cradle by vertical adjustment.
(iii) Next, the protractor locking screws were loosened and each protractor was adjusted vertically until the cradle lay on a plane between the horizontal axes of the protractors, Figure 64, p. 166. The locking screws were tightened and the alignment checked to ensure that the arch wire on the cradle now lay on the same plane as a line joining the points of intersection of the axes of both protractors (Figure 65).

Figure 65: The Cradle aligned with the points of intersection of the axes of both Protractors.

The purpose of these alignment procedures was to position bracket slots of the incisor unit (containing the main arch wire) so that the protractors provided a means of determining angulation of the incisor unit rod during activation. Rotation of the incisor unit during activation was around the main arch wire as it lay in the cradle. As the incisor unit rod was purposely aligned with the bracket slots of the teeth (see Figure 52, Appendix 1.2, p. 152), the rod could be positioned at angulations determined directly from the protractors; angles which represented the angles of activation of the torquing auxiliary when the rod was in those positions.
3.4 ESTABLISHMENT OF THE INCISOR SCALE

Positioning the incisor unit rod to angles determined by sighting across the protractors proved tedious and subject to excessive experimental error in trials. Therefore, a scale derived from the protractors was established and the scale slide employed to ensure accurate positioning of the incisor unit rod to predetermined inclinations.

The scale was established in the following manner:

(i) It was decided to employ a scale ranging from 40° to 110° in 10° increments. Because of the 5° difference between the long axis of the incisor unit rod and that of the typodont teeth (see Figure 52, Appendix 1.2, p. 152), the range of the scale represents angulations of central incisors in vivo, of between 45° and 115° relative to the plane of the main arch wire.

(ii) The trial incisor unit assembly used for positioning the incisor unit cradle and the protractors was inserted in the frame assembly as described in Appendix 3.2.2, p. 164) with the incisor unit rod resting on its table.

(iii) The incisor unit rod was raised until its upper edge lay level with the 40° graduations of the protractors. This was determined by a visual sighting, perpendicular to the protractors. The scale slide was moved until its knife edge contacted the upper edge of the rod and the lock screw tightened to immobilise the scale slide. Tightening the screw also had the effect of constricting the incisor rod guide bars slightly, so that the rod was held firmly between them.

(iv) The angulation of the rod was rechecked by sighting across the protractors to ensure that it was precisely 40°. Small adjustments of both rod and scale slide were made, after slightly loosening the locking screw until this was achieved.

(v) Using a razor blade, a fine mark was made on one incisor rod guide bar indicating the position of the knife edge.
(vi) Then, (iii) and (iv) were repeated and the accuracy of the mark made with the razor blade verified.

(vii) The locking screw of the scale slide was loosened and (iii), (iv), (v) and (vi) repeated for incisor unit rod angulations of 50°, 60°, 70°, 80°, 90°, 100° and 110°.

(viii) Black ink was washed into the fine marks of the scale to enhance their visibility. Instant numbering was applied to clearly distinguish between the various divisions of the scale.
APPENDIX 4 - MEASUREMENT METHOD

A standard procedure was employed for taking the raw measurements scores. This procedure was followed to minimise the chance of mistakes being made in the taking and tabulating of the measurements. The standard method used was as follows.

1. The incisor unit assembly was inserted into the frame assembly, as described in Appendix 3.2.2, p. 164, and the incisor unit rod was placed on the perspex shelf in the rest position.

2. The travelling microscope was manipulated, using the length and breadth adjustment knobs (see Figure 54, Appendix 1, p. 154) to position the microscope eyepiece over that end of the main archwire which was closest to the observer (designated the NEAR END). The focus adjustment was then used to focus the cross-hairs of the eyepiece and then further fine positioning was carried out so that the cross-hairs were precisely positioned over the arch end, as illustrated in Figure 35, p. 105.

3. The position of the arch end relative to the microscope table was then recorded, by reading from the length and breadth scales (see Figure 54). The readings, NBE (Near End Breadth) and NLR (Near End Length) were recorded in tabulated form.

4. The eyepiece was then positioned over the intermaxillary circle closest to the observer (designated NEAR CIRCLE) and the cross-hairs of the eyepiece positioned so that they related to the circle as illustrated in Figure 36, p. 106. The readings NBR (Near Circle Breadth) and NLR (Near Circle Length) were recorded.

5. The eyepiece was then positioned over the intermaxillary circle furthest from the observer (FAR CIRCLE) and the measurements FBR (Far Circle Breadth) and FLR (Far Circle Length) recorded. Similarly, the measurements FBE and FLE were taken at the FAR END (the arch end farthest from the observer).

The sequence described in 2-5 above was designated ONE MEASUREMENT CYCLE.
6. The incisor unit rod was then moved, using the scale slide, so that its leading edge was aligned with the 40° mark on the incisor scale and the small screw tightened to prevent any movement from that position.

7. The middle perspex plate was tapped several times with the forefinger to ensure that the main arch wire was not sticking on the teflon film.

8. A measurement cycle, as described above, was carried out.

9. The incisor unit rod was then moved to the 50° position and the measurement cycle repeated.

10. Measurement cycles were then carried out with the incisor unit rod in the 60°, 70°, 80°, 90°, 100° and 110° positions.

11. The incisor unit rod was then returned to the rest position.

The above procedure, taking measurements from 0°-110° positions was designated **ONE ACTIVATION CYCLE.**
APPENDIX 5 - STATISTICAL THEORY AND METHOD

The Linear Regression Model

As suggested earlier it is thought that the data can be described by a linear equation such that:

\[ Y = b_0 + b_1(X) + e \]

Where:
- \( Y \) is one of the four dependent variables;
- \( b_0 \) is the unknown intercept term;
- \( b_1 \) is the unknown slope coefficient;
- \( X \) is the independent variable (is ANGLE); and
- \( e \) is the unknown error.

The equation above describes the relationship between two variables in terms of a straight line. The method used to estimate this straight line is called the **Ordinary Least Squares (O.L.S.) Method**. This technique will fit a line to the data that minimises the deviations (ie errors) around the estimated line (Koutsoyiannis 1977, p. 109). This is often referred to as the line of 'best' fit. The REG procedure in SAS was used to produce estimates of \( b_0 \) and \( b_1 \) that are **Best Linear Unbiased Estimates (B.L.U.E.)** under classical assumptions.

The error term (\( e \)) in such an equation includes, amongst other types of error, measurement error (Koutsoyiannis 1987, p. 110). As long as these errors are of a random nature, the estimates will remain B.L.U.E.

**Implications of a Repeated Measures Design**

In recognition that random measurement errors may occur in taking readings, a repeated measures design was utilised. That is, each experiment was repeated five times and the measurements recorded. This procedure will improve the precision of the final estimates. However, it has inadvertently introduced an additional variable that may need to be taken into consideration: that is, it may be argued that repeated activation of the wire through the full range could significantly change the wires' elasticity. This effect has been observed before and is referred to as the Bauschinger effect.
In case successive activation cycles do produce changes in the elasticity of the wire it was decided it could be both tested and controlled for by entering it into the linear equation such that:

\[ Y = b_0 + b_1(X_1) + b_2(X_2) + e \]

where:
- \( X_1 \) is the ANGLE variable; and
- \( X_2 \) is the BLOCK variable where BLOCK takes on the values
  1 for activation cycle 1,
  2 for activation cycle 2,
  3 for activation cycle 3,
  4 for activation cycle 4,
  5 for activation cycle 5,

By entering BLOCK into the equation in this way one is able to produce an estimate of the linear displacement effect of ANGLE change (ie \( b_1 \)) on \( Y \) whilst holding the effect of BLOCK constant. It is important to remember that the block variable is not clinically meaningful and is only entered into the equation to observe whether it influences the estimate of the angle variable.

**Interpretation of the Slope Coefficient**

The slope coefficient (\( b_1 \)) represents the unit change in the independent variable (\( Y \)) for a one unit change in the independent variable (ie ANGLE). For example, if \( b_1 \) equals (0.07) then for a one degree change in the angle you would expect a (0.07 mm) increase in the distance between the arch ends.

**Test of Significance of the Ordinary Least Squares Parameter Estimates**

The least square estimates \( b_0, b_1 \) and \( b_2 \) are obtained from a sample of observations on, for example, the distance between arch ends, given differing angles. Since, sampling errors (ie measurement errors) are inevitable in all estimates, it is necessary to measure the size of the error and then determine the degree of confidence that can be attached to the estimates. There are several tests for this purpose. In this study the \( t \)-test was used to determine the statistical significance of the estimates. The \( t \)-test helps decide whether the estimates \( b_0, b_1 \) and \( b_2 \) are significantly different from zero.
Formally we test the null hypothesis;

\[ H_0 : b_1 = 0, \]
against the alternative hypothesis

\[ H_1 : b_1 \neq 0. \]

The t-test may be briefly outlined as follows;

\[ t = \frac{b_1}{s_{x_1}} \]

where \( s_{x_1} \) is the standard error of \( b_1 \).

The t-statistic, in combination with other information, is then used to determine what level of confidence can be placed in either accepting or rejecting the null hypothesis. For example, if it was found that the parameter estimate was statistically significant at the one percent level then there is only one chance in one hundred that it would be incorrect to state that the true parameter estimate was different from zero.

**Testing the Overall Significance of the Model**

To test the overall significance of the model, an F-test was used. This test helps attach a level of confidence to the decision on whether the independent variables actually affect the dependent variable. Formally the test of the overall significance of the regression implies testing the null hypothesis;

\[ H_0 : b_1 = b_2 = \ldots = b_k = 0 \]

against the alternative hypothesis

\[ H_1 : \text{not all } b_i's \text{ are zero.} \]

If the null hypothesis is true, that is if all the true parameters are zero there is no linear relationship between the dependent and independent variables.

**Measuring 'Goodness' of Fit**

After the estimation of the parameters and the determination of the OLS regression line, it is necessary to determine how well this model or line fits the data. One way to do this is to measure the dispersion of observations around the regression line. The closer the observations to the line, the better the goodness of fit.
A measure that captures the goodness of fit of the model is the **r-squared statistic** (i.e., the square of the correlation coefficient) which reflects the proportion of total variation of the dependent variable that can be explained by the independent variables. The value of $r^2$ varies between 0 and 1. If $r^2 = 0$ this indicates that the independent variables do not explain any of the variation in the dependent variable. Alternatively if $r^2 = 1$ then this indicates that the independent variables explain 100 percent of the variation in the dependent variable. That is, the closer $r^2$ is to unity, the better the model fit to the data.
APPENDIX 6: RAW MEASUREMENTS

DEFINITIONS:

TYPE: 0 = Circles free, 1 = circles fixed
DEGREES: = Angle of activation
BLOCK: = 1 to 5 activation cycles
NBE: = near breadth end
NLE: = near length end
NBR: = near breadth ring
NLR: = near length ring
FBE: = far breadth end
FLE: = far length end
FBR: = far breadth ring
FLR: = far length ring

Tables 9-18: Raw measurements 177-179
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Table 16:
APPENDIX 7 - REGRESSION ANALYSIS RESULTS

- ANALYSIS OF VARIANCE
- PARAMETER ESTIMATES

DEFINITIONS:

BREND = END BREADTH
BRING = CIRCLE BREADTH
FLENGTH = FAR LENGTH
NLENGTH = NEAR LENGTH
MODEL 1 = EXCLUDING BLOCK VARIABLE
MODEL 2 = INCLUDING BLOCK VARIABLE

Tables 19-35: Regression Analysis Results
- Analysis of Variance
- Parameter Estimates
### Table 19: End Breadth, circles free, full range.

#### DEP VARIABLE: BREND

**ANALYSIS OF VARIANCE**

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- **ROOT MSE**: 0.4449712
- **R-SQUARE**: 0.9807
- **ADJ R-SQ**: 0.9802

**PARAMETER ESTIMATES**

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR H0: PARAMETER=0 | PROB > |T| |
|----------|----|--------------------|----------------|------------------------|---------|T| |
| INTERCEPT| 1  | 39.77565217        | 0.15339867     | 259.500               | 0.0001  |T| |
| DEGREES  | 1  | 0.07633855         | 0.002074689    | 16.705                | 0.0001  |T| |

### Table 20: End Breadth, circles free, clinical range.

#### DEP VARIABLE: BREND

**ANALYSIS OF VARIANCE**

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- **ROOT MSE**: 0.2095643
- **R-SQUARE**: 0.9251
- **ADJ R-SQ**: 0.9233

**PARAMETER ESTIMATES**

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR H0: PARAMETER=0 | PROB > |T| |
|----------|----|--------------------|----------------|------------------------|---------|T| |
| INTERCEPT| 1  | 41.96200000        | 0.36524701     | 114.855                | 0.0001  |T| |
| DEGREES  | 1  | 0.07300000         | 0.009010204    | 18.204                 | 0.0001  |T| |
### Table 21: End Breadth, circles free, clinical range, Block variable.

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### Table 22: End Breadth, circles fixed, clinical range.

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DEP VARIABLE: BREND

ANALYSIS OF VARIANCE

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<th>ADJ R-SQ</th>
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<td>C.V.</td>
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PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > | T |
|----------|----|--------------------|----------------|-----------------------|---------|
| INTERCEP | 1  | 32.52200000       | 0.43151206     | 70.244                | 0.0001  | 0.0001 |
| DEGREES  | 1  | 0.04940000000     | 0.00430340101  | 10.905                | 0.0001  | 0.176  |
| LOCK     | 1  | 0.06800000        | 0.00430340101  | 15.501                | 0.0001  |        |

Table 23: End Breadth, circles fixed, clinical range, Block variable.

DEP VARIABLE: BRING

ANALYSIS OF VARIANCE

<table>
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<tr>
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<td>0.04500000</td>
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<td>0.07615773</td>
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<td>0.1834772</td>
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PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > | T |
|----------|----|--------------------|----------------|-----------------------|---------|
| INTERCEP | 1  | 40.33800000       | 0.09812237     | 411.099               | 0.0001  | 0.0001 |
| DEGREES  | 1  | 0.01300000        | 0.001077033    | 12.070                | 0.0001  |        |

Table 24: Circle Breadth, circles free, clinical range.
DEP VARIABLE: BRING

ANALYSIS OF VARIANCE

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<tr>
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<td>C TOTAL</td>
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<td>0.9784000000</td>
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ROOT MSE  0.0763911  R-SQUARE  0.8688
DEP MEAN  41.508    ADJ R-SQ  0.8568
C.V.       0.1840515

PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO1 PARAMETER=0 | PROB > |T| |
|----------|----|--------------------|----------------|------------------------|--------|
| INTERCEP | 1  | 40.308000000       | 0.10362871     | 398.966                | 0.0001 |
| DEGREES  | 1  | 0.013000000       | 0.001089044    | 12.033                 | 0.0001 |
| BLOCK    | 1  | 0.010000000       | 0.001089044    | 0.926                  | 0.3647 |

Table 25: Circle Breadth, circles free, clinical range, Block variable.

DEP VARIABLE: BRING

ANALYSIS OF VARIANCE

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<th>SOURCE</th>
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<th>PROBF</th>
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<td>0.000800000</td>
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<td>0.001089044</td>
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<tr>
<td>C TOTAL</td>
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<td>0.0800000000</td>
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ROOT MSE  0.05868116  R-SQUARE  0.0100
DEP MEAN  38.08      ADJ R-SQ  -0.0330
C.V.       0.1540997

PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO1 PARAMETER=0 | PROB > |T| |
|----------|----|--------------------|----------------|------------------------|--------|
| INTERCEP | 1  | 38.041000000       | 0.07560538     | 503.192                | 0.0001 |
| DEGREES  | 1  | 0.0004000000       | 0.000829877    | 0.482                  | 0.6344 |

Table 26: Circle Breadth, circles fixed, clinical range.
### Table 27: Far Length, circles fixed, clinical range, Block variable.

| VARIABLE | DF   | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > |T|  |
|----------|------|--------------------|----------------|------------------------|--------|--------|
| INTERCEP | 1    | 37.984000000       | 0.07036528     | 539.812                | 0.0001 |
| DEGREES  | 1    | 0.000400000        | 0.000733609    | 0.345                  | 0.5911 |
| BLOCK    | 1    | 0.020000000        | 0.0007336088   | 2.726                  | 0.0129 |

### Table 28: Far Length, circles free, clinical range.

| VARIABLE | DF   | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > |T|  |
|----------|------|--------------------|----------------|------------------------|--------|--------|
| INTERCEP | 1    | 22.125000000       | 0.08919262     | 248.059                | 0.0001 |
| DEGREES  | 1    | -0.004740000       | 0.000929897    | -5.097                 | 0.0001 |
| BLOCK    | 1    | 0.038000000        | 0.0009298974   | 4.086                  | 0.0005 |
DEP VARIABLE: FLENGTH

ANALYSIS OF VARIANCE

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<th>F VALUE</th>
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<td>MODEL</td>
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<td>0.11233800</td>
<td>0.11233800</td>
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<td>0.27965600</td>
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 ROOT MSE | 0.08529183 | R-SQUARE | 0.4017 |
 DEP MEAN  | 21.8124   | ADJ R-SQ | 0.3757 |
 C.Y.      | 0.3910245 |          |        |

PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > |T|  |
|----------|----|--------------------|----------------|-----------------------|---------|
| INTERCEPT| 1  | 22.36220000        | 0.03589698     | 622.955               | 0.0001  |
| DEGREES  | 1  | 0.0003800000       | 0.000394021    | 0.964                 | 0.3449  |

Table 29: Far Length, circles free, clinical range, Block variable.

DEP VARIABLE: FLENGTH

ANALYSIS OF VARIANCE

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<th>F VALUE</th>
<th>PROB&gt;F</th>
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<td>0.0007220000</td>
<td>0.000722000</td>
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<td>0.3449</td>
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<td>0.01785400</td>
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<td>24</td>
<td>0.01857600</td>
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 ROOT MSE | 0.02786146 | R-SQUARE | 0.0389 |
 DEP MEAN  | 22.3964   | ADJ R-SQ | -0.0029 |
 C.Y.      | 0.1244015 |          |        |

PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > |T|  |
|----------|----|--------------------|----------------|-----------------------|---------|
| INTERCEPT| 1  | 22.36220000        | 0.03589698     | 622.955               | 0.0001  |
| DEGREES  | 1  | 0.0003800000       | 0.000394021    | 0.964                 | 0.3449  |

Table 30: Far Length, circles fixed, clinical range.
DEP VARIABLE: FLENGTH

ANALYSIS OF VARIANCE

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<th>SOURCE</th>
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<th>MEAN SQUARE</th>
<th>F VALUE</th>
<th>PROB&gt;F</th>
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<td>C TOTAL</td>
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<td>0.01857600</td>
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ROOT MSE 0.02175483  R-SQUARE 0.4395
DEP MEAN 22.3964  ADJ R-SQ 0.3885
C.V. 0.0971354

PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR H0: PARAMETER=0 | PROB > |T| |
|----------|----|--------------------|----------------|------------------------|--------| |
| TERCCEP  | 1  | 22.39880000        | 0.02950969     | 759.032                | 0.0001 |
| GREESE   | 1  | 0.0000330000      | 0.0000307660   | 1.235                  | 0.2337 |
| DCK      | 1  | -0.01220000       | 0.003076598    | -9.955                 | 0.0007 |

Table 31: Far Length, circles fixed, clinical range, Block variable.

DEP VARIABLE: NLENGTH

ANALYSIS OF VARIANCE

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<td>2.71246400</td>
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ROOT MSE 0.3122474  R-SQUARE 0.1823
DEP MEAN 22.2212  ADJ R-SQ 0.1468
C.V. 1.405178

PARAMETER ESTIMATES

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR H0: PARAMETER=0 | PROB > |T| |
|----------|----|--------------------|----------------|------------------------|--------| |
| INTERCEP | 1  | 23.12120000        | 0.40230262     | 57.472                 | 0.0001 |
| DEGREES  | 1  | -0.01000000000    | 0.004415845    | -2.265                 | 0.0333 |

Table 32: Near Length, circles free, clinical range.
DEP VARIABLE: N_LENGTH

ANALYSIS OF VARIANCE

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ROOT MSE 0.3149752
R-SQUARE 0.2041
DEP MEAN 22.2212
C.V. 1.417454

PARAMETER ESTIMATES

| VARIABLE   | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR H0: PARAMETER=0 | PROB > |T |
|------------|----|--------------------|----------------|------------------------|--------|
| INTERCEPT  | 1  | 23.01770000        | 0.12725312     | 53.873                 | 0.0000 |
| DEGREES    | 1  | -0.01000000        | 0.004454472    | -2.245                 | 0.0351 |
| BLOCK      | 1  | 0.03460000         | 0.04454422     | 0.777                  | 0.4456 |

Table 33: Near Length, circles free, clinical range, Block variable.

DEP VARIABLE: N_LENGTH

ANALYSIS OF VARIANCE

<table>
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<tr>
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<th>F VALUE</th>
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ROOT MSE 0.02177154
P-SQUARE 0.2357
DEP MEAN 22.6312
C.V. 0.09620144

PARAMETER ESTIMATES

| VARIABLE   | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR H0: PARAMETER=0 | PROB > |T |
|------------|----|--------------------|----------------|------------------------|--------|
| INTERCEPT  | 1  | 22.557400000       | 0.02805067     | 804.166                | 0.0001 |
| DEGREES    | 1  | 0.000820000        | 0.000307896    | 2.663                  | 0.0139 |

Table 34: Near Length, circles fixed, clinical range.
**DEP VARIABLE: NLENGTH**

**ANALYSIS OF VARIANCE**

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**PARAMETER ESTIMATES**

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</table>

**Table 35:** Near Length, circles fixed, clinical range, Block variable.
APPENDIX 8 - GLOSSARY

1. **Bauschinger Effect**

The reduction of the elastic limit in compression, resulting from preload tension, is known as the Bauschinger effect (Forrest, 1962: p. 16).

According to Gullotta (1987), this phenomenon was first reported in the metallurgical literature by J. Bauschinger in 1886, but did not become the subject of more intense investigation until the 1950's.

The Bauschinger effect describes the phenomenon whereby the resistance to further plastic deformation of a wire is greater if the load is applied in the same direction as the original load than it is if the direction is reversed; i.e. the effect is manifested by the lowering of the yield strength whenever the direction of the applied force is opposite to that of the original deforming force.

In this laboratory study, the 0.020 in. diam. main archwires used were preformed by the manufacturer to arch shape. During the experiments, they were placed under load, as a side effect of the incisor torquing arch. The direction of the load was in the opposite direction to the original arch forming force. If a difference in the width between arch ends before and after one activation cycle could be observed, then the Bauschinger effect would be demonstrated.
<table>
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<th>Author(s)</th>
<th>Year</th>
<th>Title</th>
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<tr>
<td>Angle, E.H.</td>
<td>1916</td>
<td>Some new forms of orthodontic mechanism and reasons for their introduction.</td>
<td>Dent. Cosmos, 58: 969-994, (Sept.).</td>
</tr>
<tr>
<td>Kronman, J.H.</td>
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<tr>
<td>Barbieri, F.R.</td>
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<tr>
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<td>Year</td>
<td>Title</td>
<td>Journal/Reference</td>
</tr>
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<td>Begg, P.R.</td>
<td>1961</td>
<td>Light arch wire technique.</td>
<td>Am. J. Orthod., 47: 30-48, (Jan.).</td>
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<tr>
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<td>Year</td>
<td>Reference</td>
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<td>Meistrell, M.E., Jr.</td>
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Foster, H.R.  1968  Begg technique problem and analysis.  
Begg J. Theory & Treat., 4: 47-52, (Jan.).


Garcia, F.G.  1968  Auxiliary anterior torquing arch for the  
Begg technique.  

Gaudet, E.L.  1970  Tissue changes in the monkey following  
root torque with the Begg technique.  

Gildea, G.T.  1982  In: Round Table:  Current concepts in Begg  
philosophy and technique.  

Goel, Sumant  1981  Torquing with removable appliances.  

Goldson, Lars  1975  Root resorption during Begg treatment:  
a longitudinal study.  


Gullotta, Antonio  1987  The Bauschinger Effect in stainless steel  
orthodontic wires.  

Guy, L.B.  1970  Root resorption of maxillary central  
icisors incurred during tipping and  
torsional movements using Begg technique.  
Unpublished Masters thesis, University of  
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