THE ORTHODONTIC PROBLEM ASSOCIATED WITH MILWAUKEE BRACE TREATED SCOLIOTICS

A Thesis embodying original work submitted in
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1. INTRODUCTION

The use of orthopaedic forces to correct skeletal anomalies often results in unwanted side effects to the patient.

Orthopaedic surgeons use the Milwaukee Brace as a conservative method for the correction of spinal curvatures. The Milwaukee Brace is a leather and metal frame, fitting between the iliac crest and mandibulo-occipital complex. This brace places the patient in an extended position, forcing him to stretch bodily. This stretching process it is claimed, in many cases will reduce the spinal curvature.

The long term treatment of Scoliosis by the Milwaukee Brace (in some cases up to 10 to 12 years) often result in the development of abnormalities to the facio-maxillary structures. Compression of the lower face, intrusion, and malalignment of individual teeth, and malocclusions are common. Such changes are the result of pressure that develops between the mandibulo-occipital assembly of the Milwaukee Brace and the facio-maxillary structures.

Due to encouraging results, and latest modifications, the Milwaukee Brace has become increasingly popular as a means of conservative treatment of Scoliosis. With this increased use of the brace a larger number of these patients are seeking orthodontic treatment. It is the responsibility of orthodontists to offer some solution to this problem. Therefore, an outline of orthodontic programmes carried out to date are discussed in this study.

Also an account of the various types of Scoliosis and their aetiology are reviewed.

The purpose of this work is to record the effects on the facio-maxillary structures by the Milwaukee Brace and to assess the orthodontic problem of these patients.

Cephalometric roentgenogram and orthodontic study casts of 29 Milwaukee Brace patients were obtained and compared to a control group of pre-treatment orthodontic patients.

2. CLASSIFICATION.

Definition of Scoliosis: Scoliosis is defined by Taber (1958) , as a lateral curvature of the spine. Usually consisting of two curves the original (primary curve), and a compensatory curve in the opposite direction.

Classification of Scoliosis: To give some indications of its management and possible aetiology the comphrensive classification of Scoliosis given by James (1967) (P. 2.) is shown. Other classifications Arkin (1953) Cobb (1948) have been recorded.

NON-STRUCTURAL		Postural
		Compensatory
		Sciatic
		Inflammatory
		Hysterical
STRUCTURAL		Idiopathic
	Neuropathic	Post-poliomyelitis (paralytic scoliosis)
		Neurofibromatosis
		Charcot-Marie-Tooth neuropathy
		Friedreich 's ataxia
		Cerebral palsy
		Myelomeningocele
		Congenital absence of pain, etc.
	Osteopathic	Congenital vertebral anomalies (congenital scoliosis)
		Fragilitas ossium
		Senile osteoporosis
		Adolescent Kyphosis

Myopathic	Muscular dystrophy
	Arthrogryphosis multiplex congenita
	Amyotonia congenita
Thoracogenic	
Metabolic	Marfan 's
	Rickets
Extrinsic Causes	' Frame ' Scoliosis
	Irradiation scoliosis
Kyphoscoliosis	Congenital
	Neurofibromatosis

<u>NON-STRUCTURAL SCOLIOSIS:</u> This type of Scoliosis , clinically and radiographically , will show no rotation of the vertebral bodies or spinous processes on bending forward , and is without structural change (Fig. 1). Non-Structural scoliosis is usually less serious than Structural Scoliosis. James (1967)(P. 3.) summarises the following forms of Non-Structural Scoliosis.

In <u>Postural Scoliosis</u>, the spinal curve is correctable in traction or even when the patient is supine ; traction being in the form of a stretch bed or by gravitational pull on the body. (Refer to conservative methods of teatment) .

<u>Compensatory Scoliosis</u> is the development of a spinal curve to compensate for a short leg or long leg due to hip adduction or abduction . It is corrected when the shortened leg, or limb abnormalities are returned to normal.

<u>Sciatic Scoliosis</u> is usually a reflex action to relieve the pressure on the sciatic nerve root.

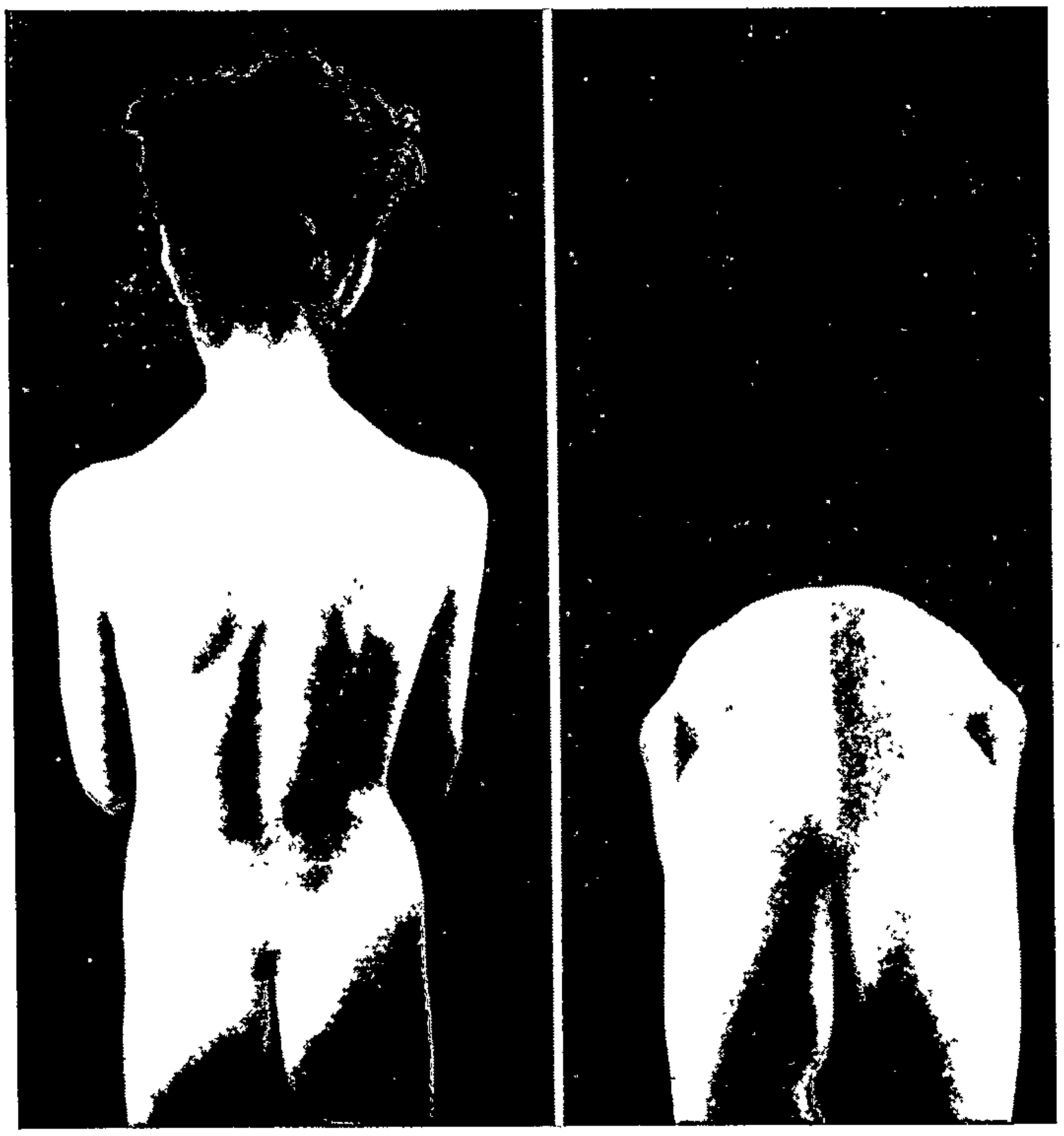


Fig. 1 POSTURAL SCOLIOSIS

Photograph of a young girl with typical Postural Scoliosis. In the upright position a small curve is seen convex to the left, but on forward flexion this disappears and there is no fixed rotation.

(From James 1967, p 31)

Hysterical Scoliosis is a rarity and is an exaggeration of the postural Scoliosis form mentioned.

Inflammatory Scoliosis may be due to spinal abscess but , when drained , the spine returns to normal.

Structural Scoliosis shows fixed posterior vertebrae and rib rotation on the convexity of the primary curve , clinically seen by bending the child forward with both feet on the ground (Fig. 2,3,4.). The primary curve is that part of the vertebral column in which structural lateral curvature with rotation has occurred.

When a single primary curve exists, Taber (1958) explains there will develop compensatory curves above and below it and in the opposite direction. These will return the head to a position vertically above the pelvis in accord with the horizontal ocular righting reflex. Compensatory curves are sometimes called 'secondary or minor curves'. The sum of the angles of curvature of the two compensatory curves will be approximately equal to that of the primary curve. Compensatory curves never show clinical rotation and do not need treatment.

The commonly used method of measuring the angulation of the lateral curvature of the spine is by the Cobb method (Cobb 1948). For explanation see Fig. 5. Taber (1958) defines the following various angular deformities of the spine which are linked or often part of scoliosis. Kyphosis is a convex backward curvature of the spine (Humpback). Lordosis is an abnormal anterior convexity of the spine. Kyphoscoliosis is a combination of forward bending and lateral curvature of the spine. Lordoscoliosis is a combination of lordosis and scoliosis, backward bending and lateral curvature of the spine.

Fig. 2

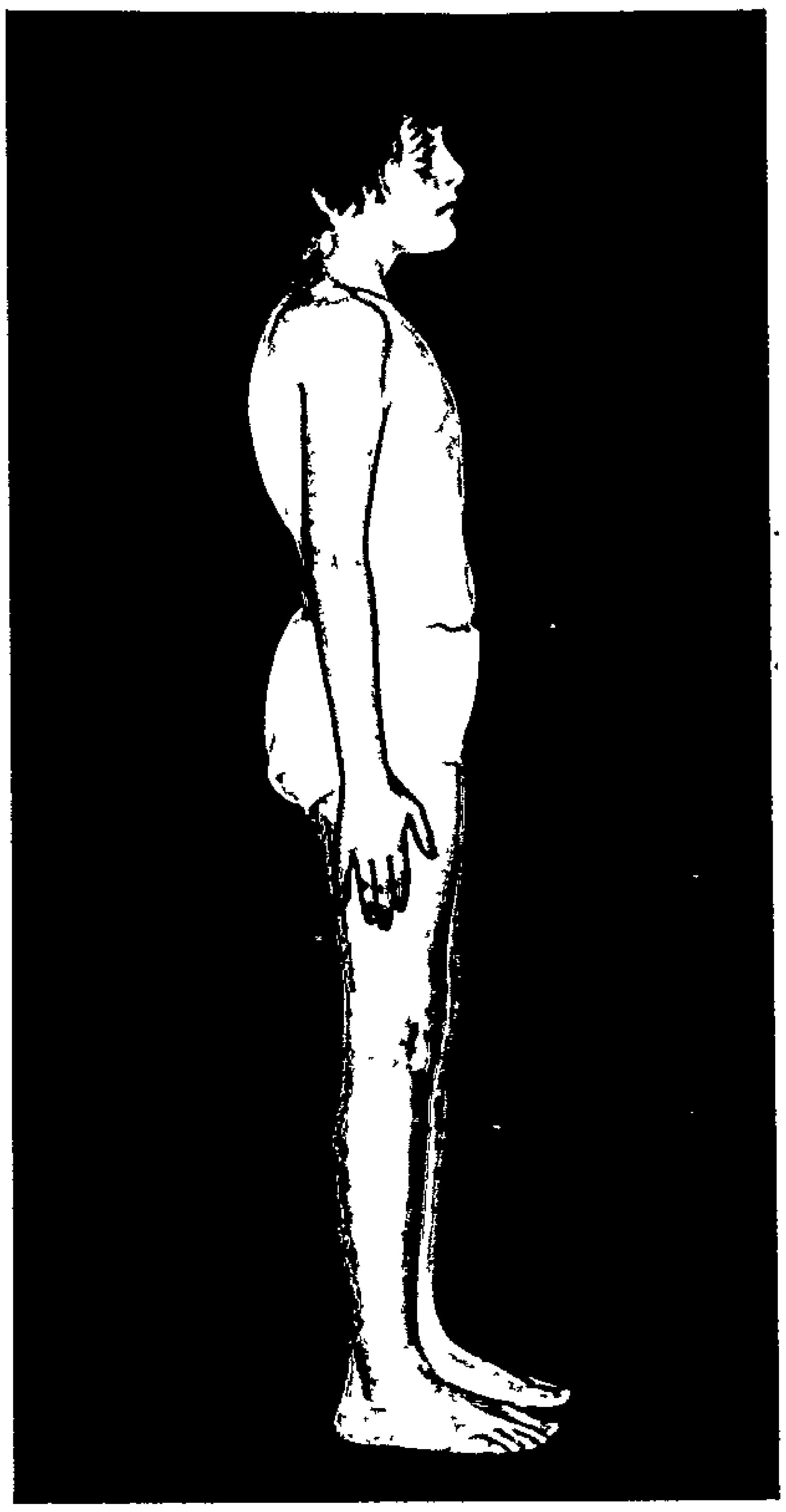
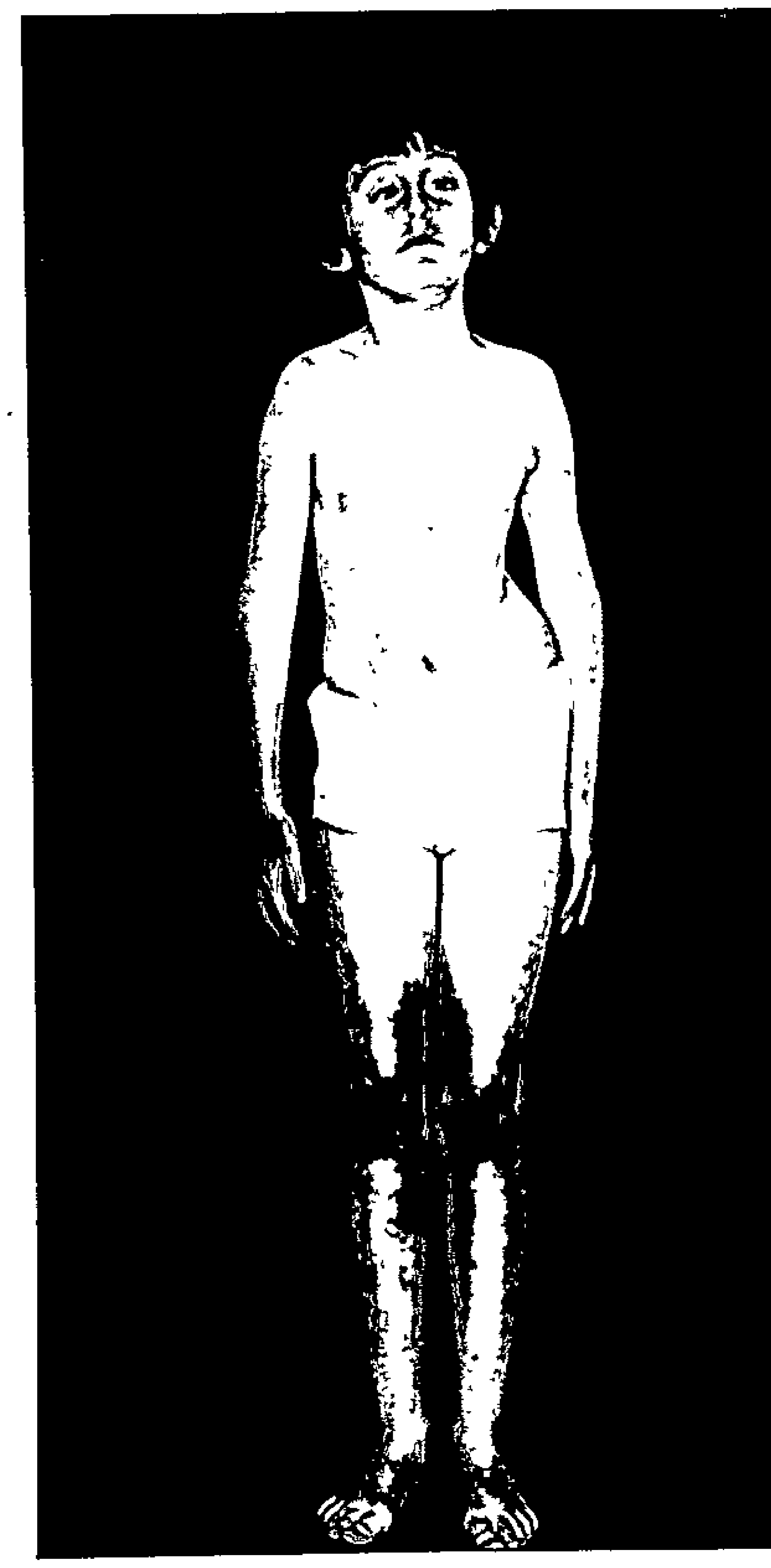


Fig. 3



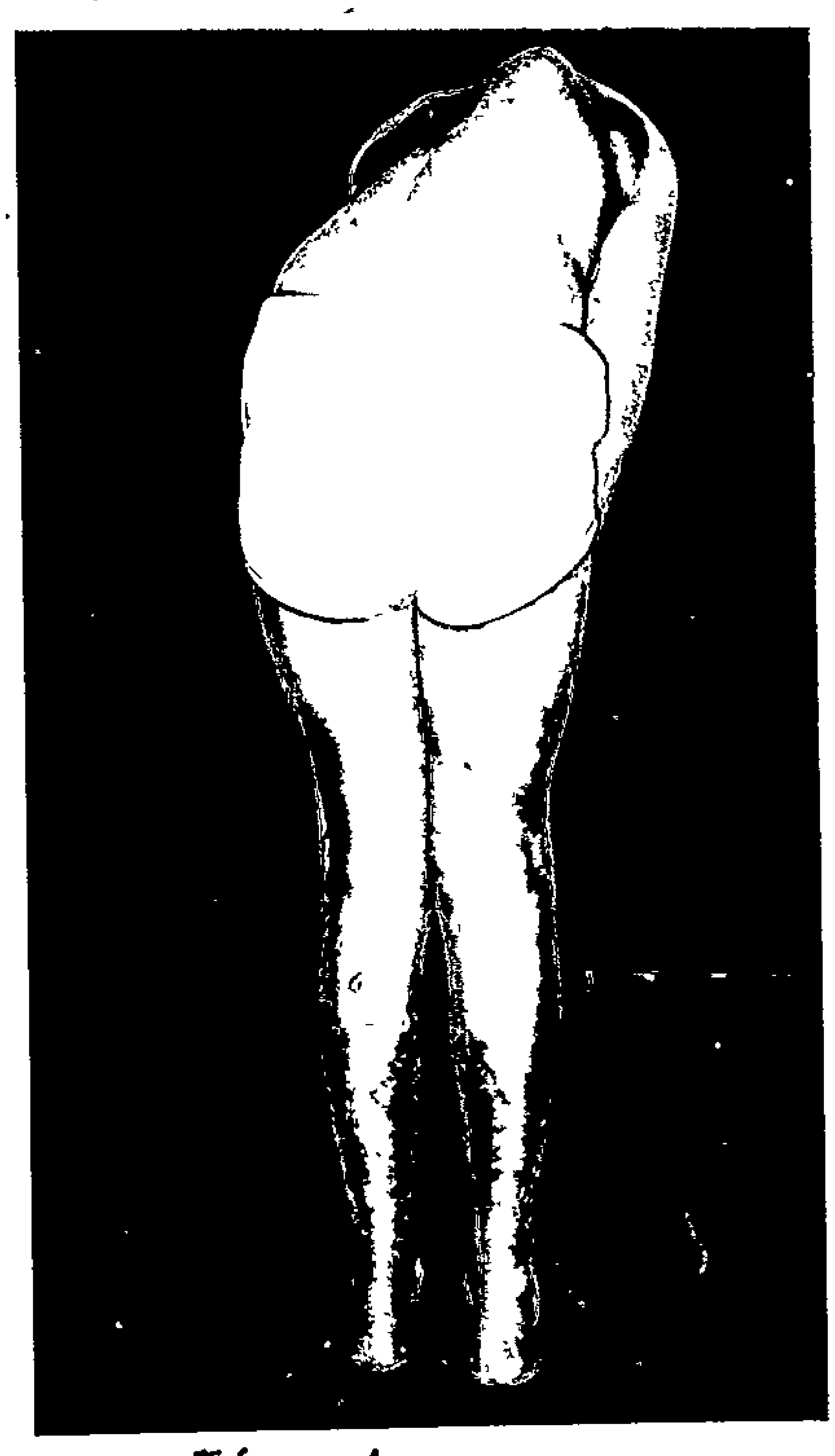


Fig. 4

Fig. 2, 3, 4.

Idiopathic Scoliosis.

This girl has a lumbar thoracic curvature of approximately 70°. The severity of spinal curvature is apparent when the patient bends forward.

Fig. 5

The primary curve extends between T5 and L2 by all three radiological criteria. Lines have been drawn parallel to the upper border of the upper vertebra (T5) and the lower border of the lower vertebra (L2). Perpendiculars erected from these intersect and allow measurement of the angle of curvature by Cobb's method.

(From James. 1967, P.7)

The three commonest forms of scoliosis which the orthopaedic surgeon treats are structural,

(i) Idiopathic

(ii) Paralytic

(iii) Congenital

(i) Idiopathic Scoliosis

James (1954) reports it as a lateral structural curvature of the spine of unknown aetiology and the commonest form of scoliosis. It is diagnosed by exclusion of other possible types. It is seen at all ages in both sexes during growth and affects the lumbar and thoracic vertebrae. It is peculiar in that it has three peak periods of onset: 1st year of life, 5-6 years and after the 11th year. (Fig. 6). Recent work by Vanderpool (1969) shows a high incidence of scoliosis after the age of fifty, being six per cent in healthy people and 38 per cent in people with osseous diseases.

Studies on idiopathic scoliosis show that prognosis depends on curve pattern and age of onset: the younger the patient and the higher the curve in the vertebral column the worse the prognosis. (Ponseti and Friedman 1950) and (James 1954).

Goldstein (1966) points out the importance of sketetal age and the development of physical attributes characteristic of puberty. Arkin (1953) believed Idiopathic Scoliosis to be a gravitational disease, the progressing deformity being due to a shift of body weight over to the concave side. Lloyd-Roberts and Pilcher (1965) have shown that in the Infantile Idiopathic Scoliosis the curve resolves in 90 per cent of cases, with progression to serious deformity in the other 10 per cent.

Four basic curve patterns are detectable in Idiopathic Scoliosis with the body deformity at times giving no indication of the gross skeletal deformity. (Fig. 7.)

IDIOPATHIC SCOLIOSIS-AGE OF ONSET-180 PATIENTS

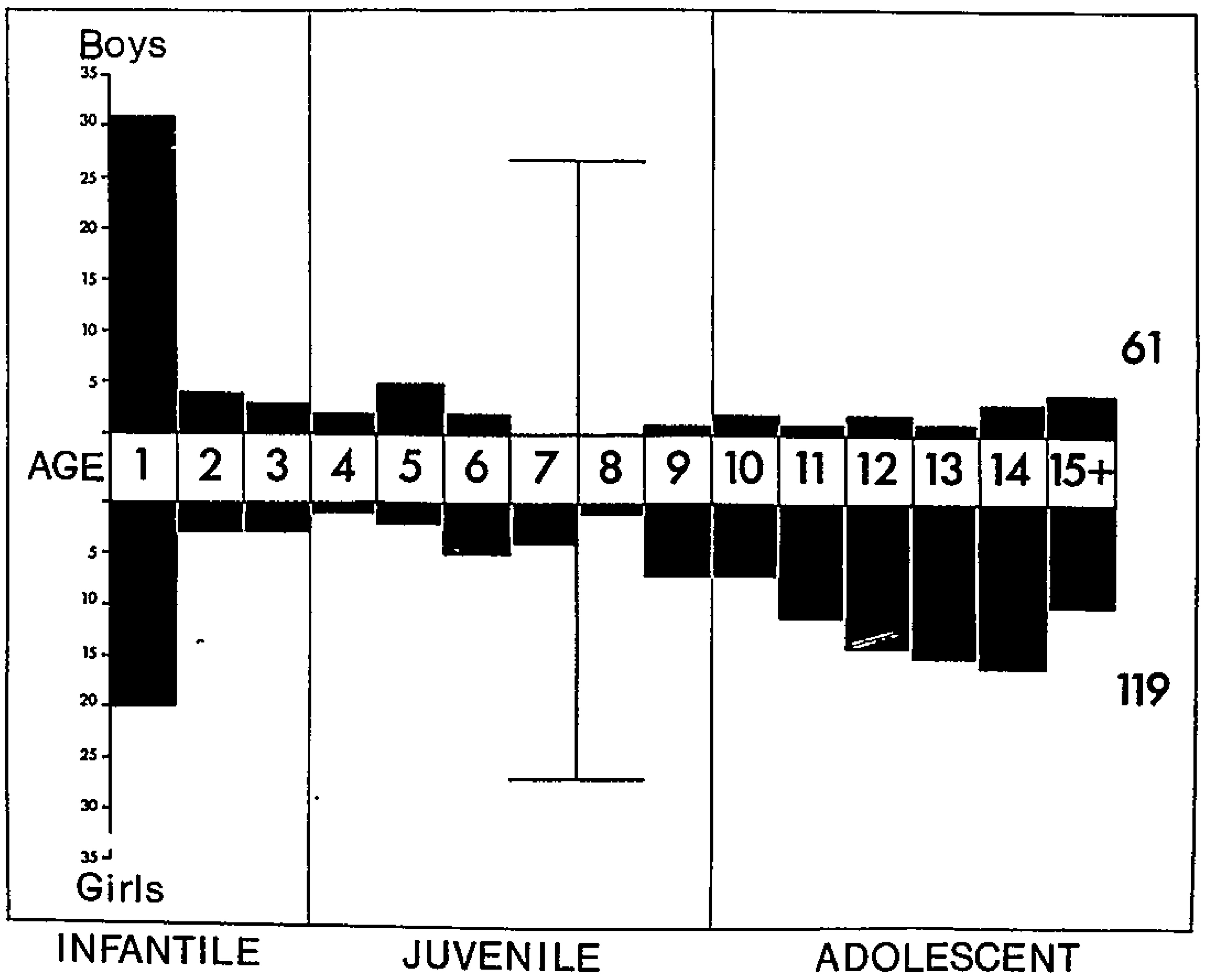


Fig. 6

A histogram constructed from the ages of onset in 180 patients with idiopathic scoliosis. There is a large peak at the age of one year, a small increase at 5-6 years of age; again from the 11th year.

(From James 1967, p. 36)

The subclassification given by James (1967) (P.39) is,

(a) Lumbar Idiopathic Scoliosis occurs with a primary curve in lumbar region, most commonly seen in the adolescent girl with either left-and-right-sided curve. The iliac crest on the concave side becomes prominent and there is always a compensatory curve above and below the primary curve.

(b) Thoraco-lumbar Idiopathic Scoliosis is the least common of the patterns of idiopathic scoliosis, with the curve apex near the thoraco-lumbar junction. Like the lumbar form, it is uncommon under the age of ten.

(c) Thoracic Idiopathic Scoliosis is the commonest form seen in adolescent girls mainly on the right side. This presents with dropped shoulder and prominent iliac crest.

(d) Double Primary Curve Idiopathic Scoliosis has a curve pattern which may occur at an early age. These children radiographically show an almost equal double curve pattern, with often little outward body deformity. There are two primary curves present doubled back on each other. On rare occasions, Triple Primary Scoliosis has been recorded.

It is interesting to note at this stage, the high incidence of Infantile Idiopathic Scoliosis which people in the European countries have, (Wynne-Davies 1967), and yet it is almost absent in America. In time, this peculiar aspect of scoliosis occurrence may shed more information on its aetiology. The importance of this peculiarity will be discussed under aetiology. It is well to realise that various types of scoliosis are found in varying degree in particular geographical areas.

Fig. 7

Four girls each with 70 degrees of curvature. From left to right, lumbar, thoraco-lumbar, thoracic and double primary curves. The last girl has two curves 68 and 66 degrees, a total of about 140 degrees, but she is the least deformed. It is clear that the thoracic curve with its dropped shoulder, prominent iliac crest and large rib rotation is the ugliest, and it also has the worst prognosis for expected severity in degrees of the curvature.

(From James 1967, p 53)

(ii) Paralytic Scoliosis

This is the form of scoliosis following poliomyelitis, is thought to be mainly due to muscle imbalance in the growing child. Farkas (1943) points out that paralytic scoliosis is characterised by a high degree of flexibility and compressibility. (Fig. 8) The resulting mobility and compressibility results in a translatory shift of the vertebrae, thus causing lateral curvature. Factors affecting prognosis are positions of the primary curve, age of onset of polio and the degree of muscle imbalance.

The common curve patterns of 193 patients (James 1956) show thoracic, high thoracic and thoraco-lumbar were most prominent in that order. A feature noticed in the high thoracic paralytic scoliosis is that, like idiopathic scoliosis, curves are most often to the right. However, where females are more likely to suffer from idiopathic scoliosis, paralytic scoliosis appears in equal numbers in both sexes.

Paralytic Scoliosis may offer difficulties in management, in that it may involve many vertebrae. (Paron and Manning, 1970). Also collapse of the spines and vertebral body deformity, may occur suddenly without warning. It has been shown that patients who develop paralytic scoliosis do so within the first two years of an acute attack of poliomyelitis.

Paralytic Scoliosis can be differentiated from scoliosis of any other aetiology by uniform density of the spine in the roentgenogram, by excessive and early rotation of the vertebrae, and by the temporary concave rotation. (Farkas 1943).

Lumbar Scoliosis presents in two forms: those due to muscle imbalance which rapidly increases and early develops a fixed rotation and those with a 'collapsing' spine, which develops a sag from the effect of gravity and lack of muscle support. (James 1967)(P.83).

The importance of muscle/gravity will be discussed more fully under aetiology.

Fig. 8

This boy has severe trunk paralysis without very much muscle imbalance. His curve is largely the result of gravity and characteristically remains mobile for a very long time. The ease of partial correction of stretching is well shown and is a very familiar pattern in paralytic lumbar scoliosis of the collapse or gravity type.

(From James 1967, p. 56)

Generally, the prognosis of paralytic scoliosis is poor (Arkin 1953), particularly if large amounts of growth remain. Such complications as respiratory insufficiency, backache, and associated paralysis of other limbs and cardiac failure have been reported by Bergofsky, et al. (1959).

(iii) Congenital Scoliosis

This scoliosis is due to congenital vertebral anomalies which may be single or multiple, the curve itself being initiated by asymmetrical width and depth of vertebrae (Fig. 9). The basic classification of congenital scoliosis listed by Winter, et al (1968) is,

(a) Unilateral failure of vertebral formation, partial (wedged vertebra),
(b) Unilateral failure of vertebral formation, complete (hemivertebra),
(c) Symmetrical failure of spinal segmentation (congenital fusion).
(d) Asymmetrical failure of segmentation (unsegmented bar).

Congenital Scoliosis presents as an irregular pattern in the primary curve with fixed rotation, and a not-uncommon lordosis over the primary curve. It is commonly seen in the child at birth who may show no curvature initially, but will do so later. An important change associated with this type of scoliosis is an irregular growth pattern, many children presenting with a shortened trunk.

Many congenital scoliotics often have associated disorders of skin and soft tissue, in some cases these are severe, e.g. Klippel Feil syndrome (Winter, et al 1968). Congenital Scoliosis is often severely deforming with rapid increase in curvature without formation of a compensatory curve. Marked rotation of vertabral bodies often leads to confusion that a kyphoscoliosis is present, though this is a separate entity. The degree of kyphosis or lordosis in scoliosis is difficult to determine.

The remaining types of scoliosis (refer to classification) are usually associated with, or part of, some syndrome, or primary disease. Though these types of scoliosis are less common, they are usually severe and more difficult to treat. e.g. Neurofibromatosis (Von Recklinghausen's disease) Syringomyelia, Friedreich's ataxia, (Curtis, et al. 1969).

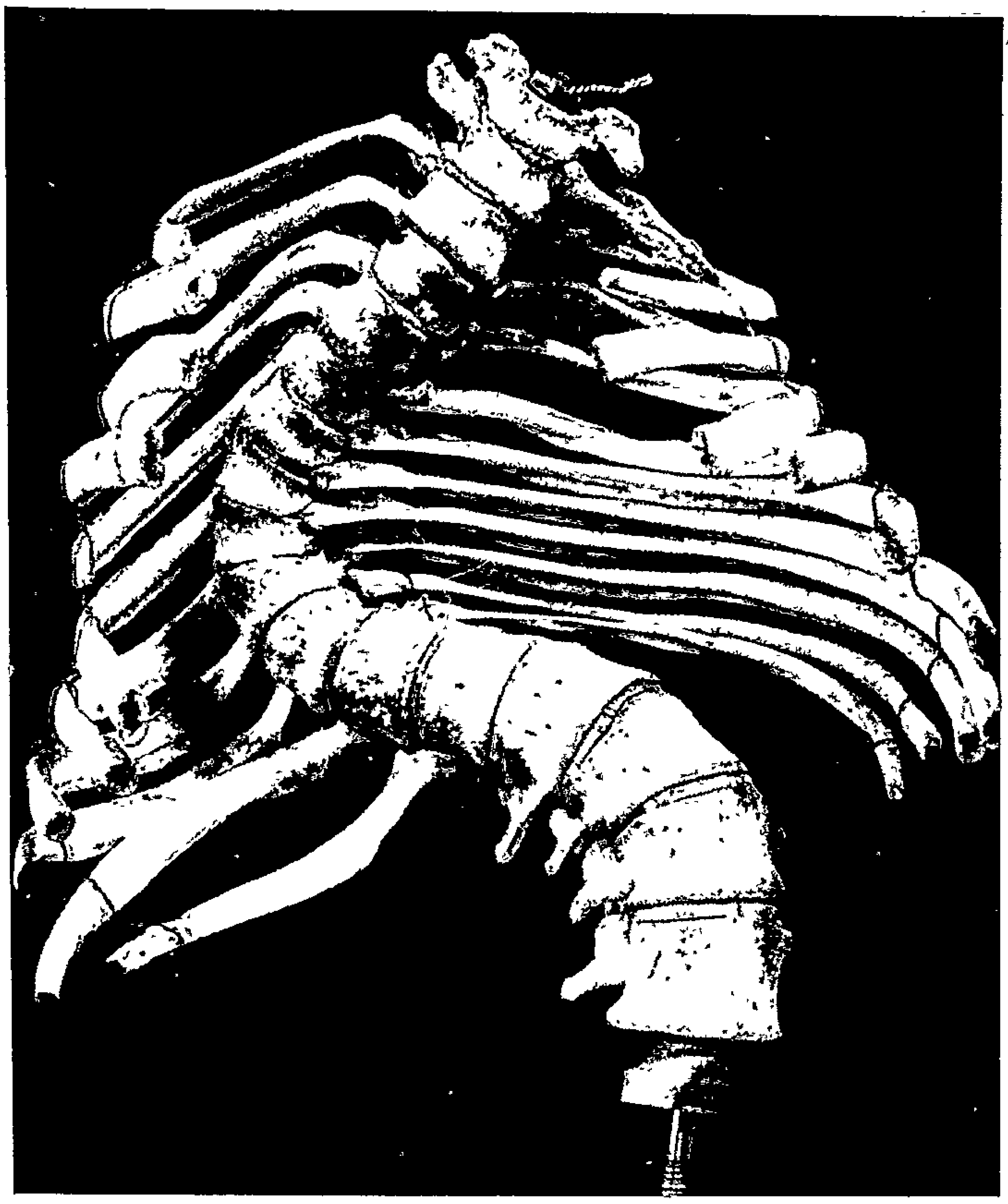


Fig. 9

A dried specimen showing a thoracic scoliosis with rotation of the bodies to the convexity of the curve, the ribs being curved back with the vertebrae. Note the wedging of the vertebral bodies on the concavity.

(From James 1967, p.13)

3. AETIOLOGY OF SCOLIOSIS

The aetiology of Idiopathic Scoliosis is unknown though many observations and investigations have been carried out. As James (1970) puts it, "it is a curious disease few of us even have a hypothesis of causation".

In paralytic scoliosis and scoliosis due to muscular dystrophies, the mechanism of muscular balance is at fault. In congenital scoliosis bone anomalies within the vertebral bodies cause curvature of the spine. The numerous diseases associated with scoliosis also gives some clue on which aspects to approach the aetiology.

The following observations will show the pattern and function of the disease and the complexity in trying to find a specific cause.

(i) Experimental Scoliosis .

Langenskiold and Michelsson (1961) produced scoliosis in animals by unilateral resection of the posterior ends of the 6th to 11th ribs including the costal parts of both costo-vertebral joints. Progressive scoliosis with marked rotation was caused in rabbits, while in the other cases destruction of growth zones in 6th to 11th ribs and excision of the 6th to 11th costo-transverse muscles did not produce scoliosis. The results of this work, as it relates to human scoliosis, is difficult to evaluate, many factors having to be taken into account. Important, for example, would be the upright position of man as against the quadruped stance of animals.

Manning (1971) repeating Langenskiold's work, was able to produce scoliosis, convex toward the side of operation in young rabbits, by resection of ribs from the epiphysis at the neck to the angle. Manning went further and carried out the same operation on the opposite side when a progressive curve had been set in motion, the original curve was reduced or neutralised.

Michelsson (1965) showed with pigs that the concave side of scoliosis grows the most, not the convex side, as one would imagine, which had been a past hypothesis.

The above findings show that the structures, bone, ligament and muscle, are important in maintaining a normal spinal posture. Of the structures altered, division of the costo-transverse ligaments was the procedure that caused scoliosis consistently. Could it be that the ligamentous anomalies, not the muscle or bone defects, hold the vital clue? Ligamentous anomalies are a constant factor in experimental and metabolic studies in scoliosis. Ponseti and Shepard (1954) showed that when rats are fed on diets containing (Lathyrus odoratus) seeds loosening and detachment of the tendinous and ligamentous insertions occur and scoliosis may result.

Roaf (1966) found in scoliotic spines with severe curves, that the anterior longitudinal ligament is longer than the posterior. James (1970) points out that the most classical form of Idiopathic Scoliosis is in the adolescent girl. It seems possible that significant changes in bone or ligamentous formation could occur because at this pubertal period there is a large turnover of hormones. Taking into account the endocrine secretions concerned - oestrone, oestradiol, oestriol, and progesterone - all are capable of affecting bone and ligament formation.

Further association of ligamentous anomalies is seen in the excessive excretion of mucopolysaccharides as seen in Morquio's Disease, and Hurler's Disease with Idiopathic Scoliosis (Nagel 1965). Ponseti (1970) explains that the abnormal skeletal growth in Marquio's Disease seems primarily related to a disorder of ossification at sites of tendon and ligament insertions into cartilage.

(ii) Metabolism

Marfan's syndrome and Homocystinuria show severe metabolic disturbances, physical anomalies and a peculiar form of scoliosis. Ponseti and Shepard (1954) produced in rats, scoliosis not unlike that seen in humans with Marfan's Syndrome, together with some features of this syndrome. The essential substance in this is an aminonitrite, a metabolic poison interfering with the chondroitin sulphate which in the rat, causes slipping of epiphyses, ligamentous detachment, scoliosis, and aneurysm of the aorta. Homocystinuria is an inborn error of amino acid metabolism, distinguished by abnormalities of growth and development.

Beals (1969) points out that in Homocystinuria, the affected children appear normal at birth, with progressing deformities of the eyes, teeth and mental retardation. Malocclusion with a high-arched palate and mandibular prognathism may develop with growth, and a limited degree of facial expression due to weak facial muscles may also be evident. Most instances of Scoliosis in these patients develop as a left lumbar or right thoracic curve, the lumbar curve being greater.

Crowe, et al (1956) indicated that neurofibromatosis, in which scoliosis may be one of the defects, is due to a dominant inheritance of an inborn error of metabolism, the nature of which is quite unknown.

(iii) Heredity

Wynne-Davies (1968), in surveyson scoliosis, found congenital and idiopathic forms have a familial content. In a study on 114 patients diagnosed as Idiopathic Scoliosis, on examination of second and third degree relatives totalling 2,000, when compared with a sample population of 11,000 children, these authors found scoliosis to be twenty times more common in the relatives of scoliotics than in the general population. This is proof that genetic causes are important. (Table 1). A surprising finding of this study, which is statistically significant, is that scoliosis is more common in the daughters of mothers over thirty years. Also, an unexpected discovery has been the association of mental disease with scoliosis. In this series, it is about seven times the incidence in the general population. The strong relationship between mental disease and scoliosis, supports the theory that scoliosis may be an inherited biochemical change since a large proportion of mental disease is known to be biochemical in origin.

Colwell, et al (1969) showed that Idiopathic Scoliosis may be inherited. In a study on 320 individuals from 75 families, they showed that one third of the family members of patients with Idiopathic Scoliosis had curves of more than 10 degrees. They further pointed out that the inheritance of scoliosis passes through to the fourth generation in a dominant mode. They suggested that a sex-linked dominant mode of inheritance with variable expressivity and incomplete penetrance existed.

Browne (1965) believes that intra-uterine foetal posture is the main cause of Infantile Idiopathic Scoliosis. Supporting evidence for this hypothesis is the high percentage of scoliotic babies born with plagiocephally (Fig. 10) Wynne-Davies (1968) found that 10 per cent of scoliotic babies had plagiocephally, this resolved in nearly all cases. However, as has been pointed out, it seems unlikely that a baby could be born straight and later develop a curve because of its previous position in utero.

An association exists between scoliosis, plagiocephally, neurofibromatosis and mandibular deformities. It has been established that a large percentage of people with neurofibromatosis suffer from scoliosis. (Hunt and Pugh, 1961). Griffith, et al (1972) in their group of patients with neurofibromatosis found 24 percent had scoliosis. Recent work by Rittersma, et al (1972) show an unusual association between neurofibromatosis and facial hemiatrophy in the form of underdevelopment of the maxilla, zygoma and mandible, believing the mandibular deformities that led to facial hemiatrophy to be congenital in origin.

TABLE 1.

Incidence of Scoliosis amongst the First Degree Relatives of the Scoliosis Patients (%)

Patients with scoliosis	*Incidence amongst first degree relatives*	*Incidence in general population*
Early onset		
38 Boys	2·5	0·12
23 Girls	2·6	0·13
Late onset		
11 Boys	0	0·03
42 Girls	6·9	0·39

165

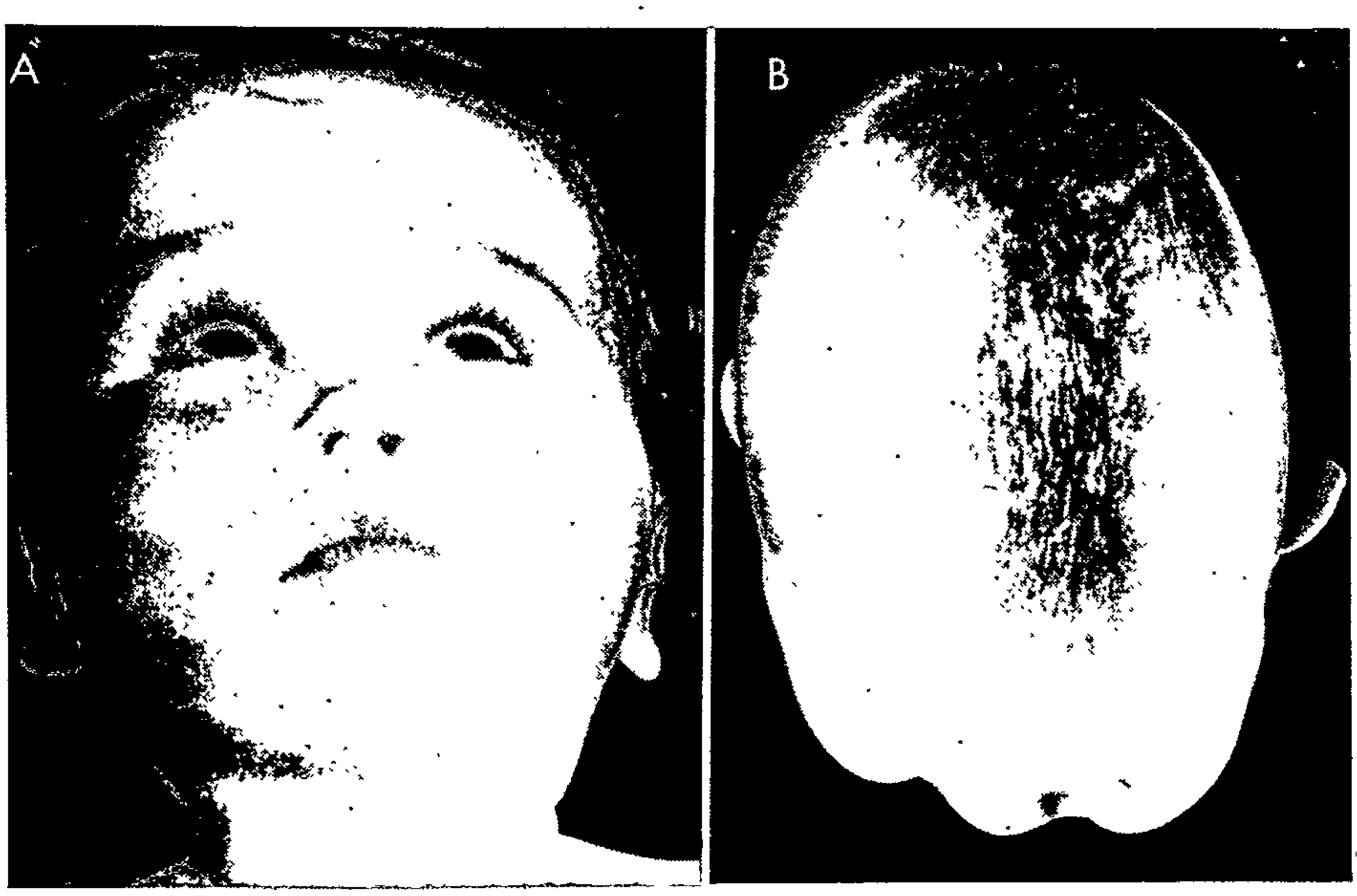


Fig. 10

Baby with plagiocephally showing a severe degree of asymmetry.

Such intrauterine pressure causing cephalic defomrities is thought to also be the cause of spinal deformities.

(iv) Growth in Scoliosis

One of the current possibilities for the cause of Idiopathic Scoliosis is put forward by Zorab (1970): it is unmatched growth of the vertebral column and growth of the surrounding muscles.

Duval-Beaupere (1970) has shown that physiological growth in scoliosis patients is normal, as evidenced in growth velocity curves.

Growth, remodelling, or repair of bone results in an increased turnover of bone and collagen which is indicated by urinary total hydroxypraline (THP).

In a study of 135 scoliosis patients, Zorab (1970) shows an abnormally high turnover of THP. Therefore, if there is a normal physiological growth in scoliotics, and an abnormally high bone collagen turnover, something must give. In this case it would be bone or ligaments or muscle attachments.

The importance of studies on biochemical analysis of urine is pointed out by Smith (1970) stating, "when you measure growth, you are measuring in the most direct way available, the end result of a series of complex biochemical changes. It is important to do this because although you may not miss the obvious, any possible growth changes may be quite subtle."

An important relationship of muscle, bone, and growth in scoliosis is shown in recent work by Langenskiold (1970). He hypothesised that by keeping the spine of growing rabbit laterally curved in a plaster jacket for three weeks, growth disturbances of muscles on the concave side must occur and result in progressive scoliosis. In 217 of his 253 experiments on rabbits, scoliosis developed. In 66, the curve gradually straightened. In 41 no progression or only slight progression was seen after the immobilization period. This was partly expected from the fact that myotatic contracture comes into play when a muscle is kept in a shortened state for a sufficient period of time. It remains, however, alteration of normal muscle growth of the spine can result in scoliosis.

Disruption of growth by radiation and resultant scoliosis has been recorded by Katzman, et al (1969). They observed changes in vertebral bodies and the formation of scoliosis, hypoplasia of the ilium, and many other skeletal anomalies. The first clinical case of radiation-induced scoliosis was reported by Arkin (1950). The deformities so produced were believed to be caused by destruction of the growth centre of the vertebral bodies on the exposed side.

It can be seen, therefore, that where Langenskiold failed to produce scoliosis by surgically deforming growth centres, radiation with resultant destruction of growth centres will cause scoliosis. This possibility suggests that the aetiology should be attacked from a cellular or biochemical level.

4. METHODS OF TREATMENT

The three basic methods of treatment employed by orthopaedic surgeons are:

(a) Conservative

(b) Correction and fusion

(c) Surgical

Risser and Norquist (1958) state that there are two objectives in the treatment of scoliosis:

. Prevent increasing deformity.

. To correct the deformity and maintain the correction.

Since increase in the scoliotic deformity occurs with growth of the spine, prevention must begin with the mild curves before vertebral growth is complete.

(i) Conservative Treatment

One of the early forms of conservative treatment was the use of gravitational pull on the body. Sayre (1876) used a suspension apparatus in which the patient was hung by means of slings under both shoulders and mandible. The patient was raised in the air by means of a pulley and suspended by his own weight.

Cobb (1958) recorded the popularity in the past of numerous mechanical devices such as the Abbot frame, the Murk Jansen plaster bed and various types of corsets, such devices are now in oblivion due to their poor success in treatment.

One person who has not discarded this form of treatment is P.R. Harrington (1970), who presents a case in which treatment consisted of a Denis Browne bucket and corset and a standing bed with a foot board. The patient's spine was corrected from 75 degrees to 10 degrees over four years of treatment. This patient was selected for this form of treatment, being diagnosed as a hemiplegic with scoliosis. Harrington believed the correction was due to controlled gravity loading of the spine.

Long believed to be beneficial in the treatment of scoliosis, but lacking in supporting evidence, is compulsory muscular exercise.

Arkin (1953) believes that exercises are of little value for the reason that, cumulatively, they are acting for such a short time. In the early times such people as Steindler (1929) believed that exercises to develop the compensatory curve were important in controlling scoliosis. However, as has been shown since then, a compensatory curve will develop of its own accord. Goldstein (1969) uses the Milwaukee Brace in conjunction with exercise, considering muscular exercise an important part of treatment.

Recent successful conservative treatment has been in the form of a plaster localiser jackets (Fig. 11), and turnbuckle casts (Fig. 12), described by Risser and Norquist (1958), and the more popular Milwaukee Brace (Fig. 13) designed by Blount and Schmidt (1958). James (1967) (P.192) indicates that conservative treatment consists of observation if the curve has good prognosis; and where the curve is severe, or potentially severe, treatment is determined by the age of the patient.

In summary, conservative treatment would follow:

0-3 years — Risser hinging plaster jacket followed by repeated spinal jackets.

3-10 years — Milwaukee Brace.

13 years and over: In smaller curves, Milwaukee Brace until growth has ceased, this is particularly applicable to the double primary curves.

It is important to realise that correction followed by fusion and or surgical instrumentation is the normal process in treatment of scoliosis. Goldstein (1969) explains the treatment of scoliosis more as a treatment program. In some

Fig. 11

The Localiser cast completed with a 'V' cut over the trachea. There is a plaster collar which extends up on the occiput behind and the mandible in front.

(From James 1967, p.198)

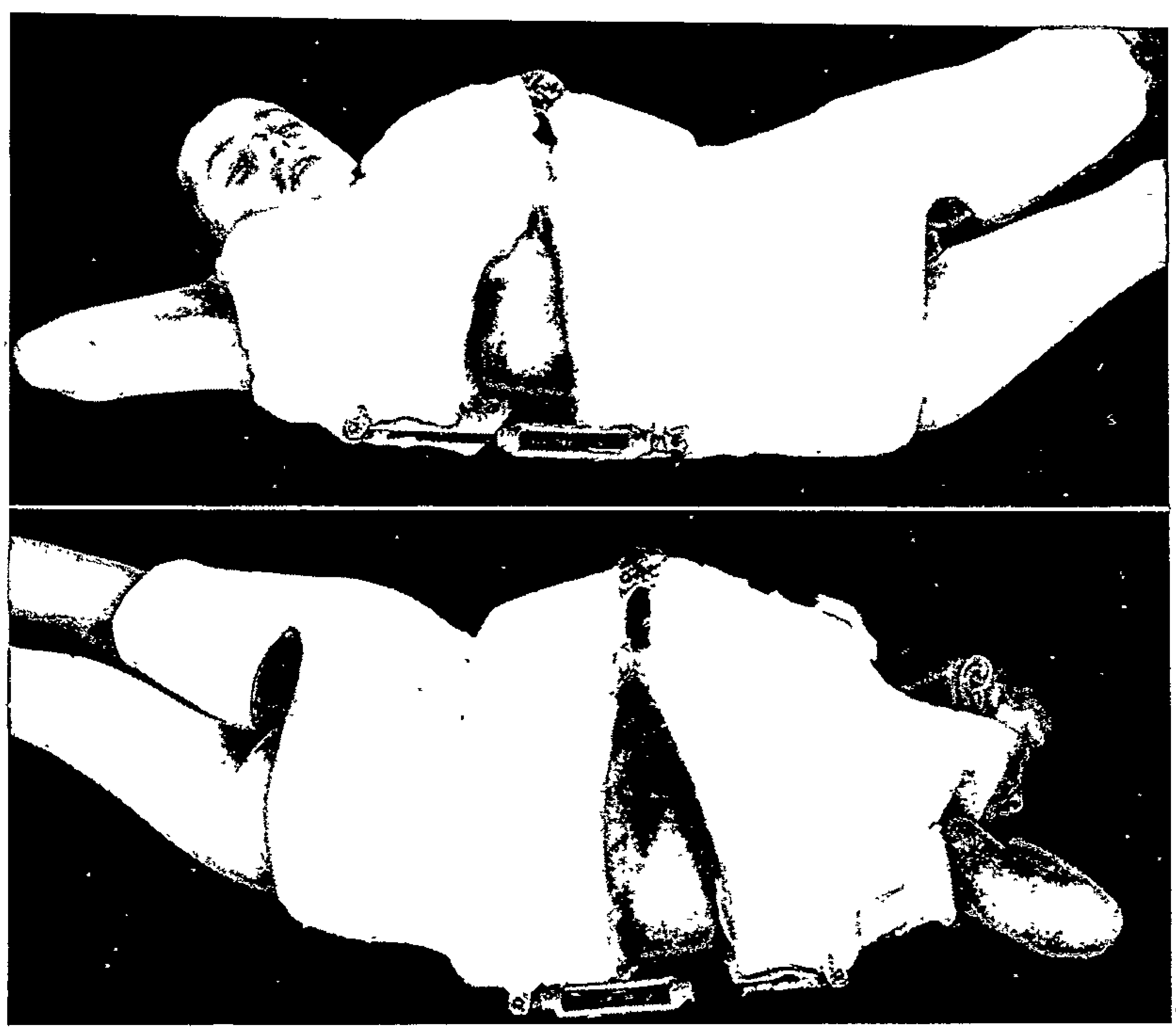


Fig. 12

The Risser Jacket. The hinges in front and behind one placed well lateral to the convex side, the jacket is then split and the turnbuckle opened steadily over a period of about three weeks. The leg on the convex side is enclosed in plaster.

(From James 1967, P. 199)

Fig. 13

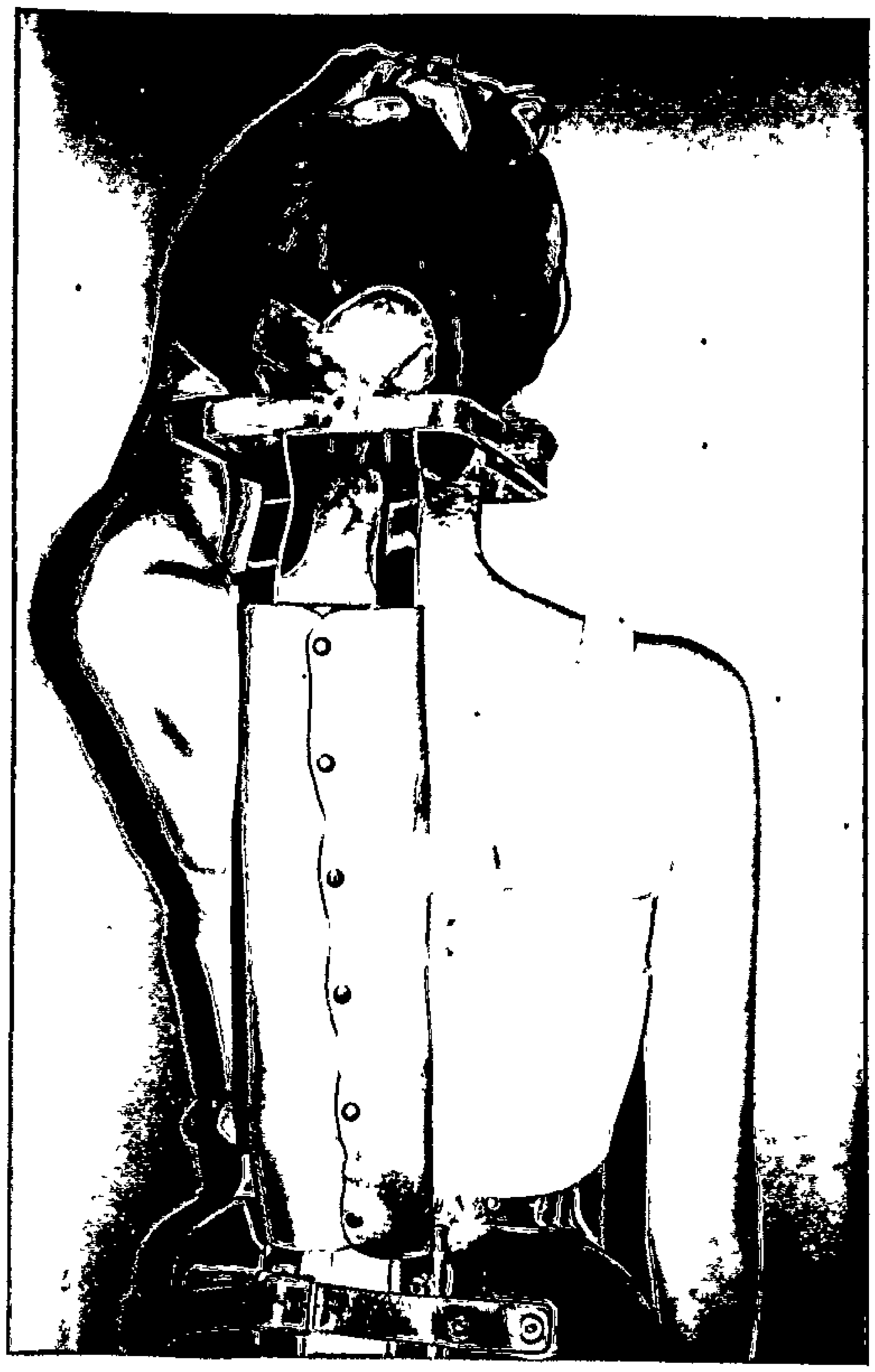
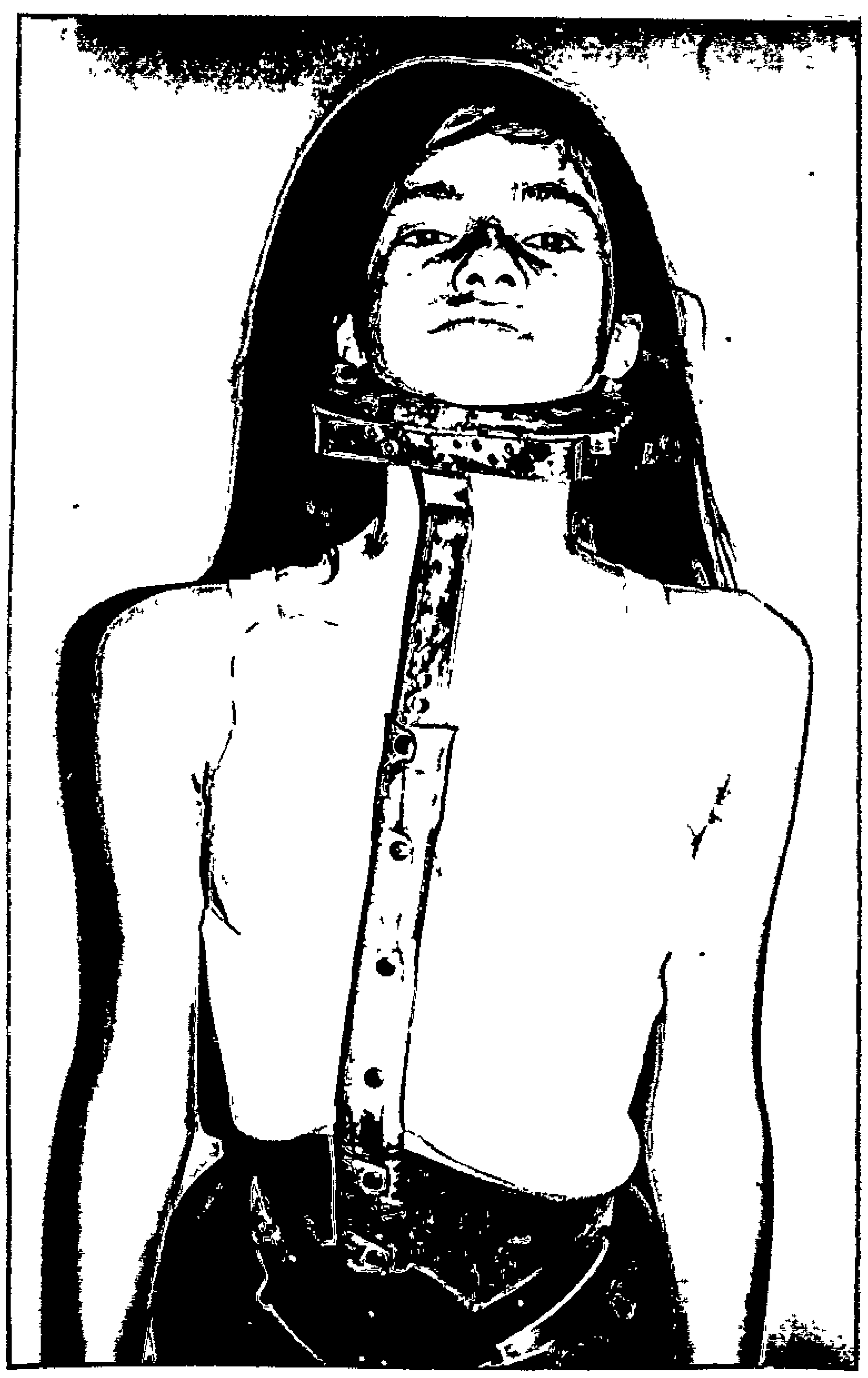


Fig. 14



The Milwaukee Brace. It consists of a leather pelvic girdle, mandibulo-occipital assembly and distraction bars. As the patient grows and is stretched, the vertical bars are extended.

Fig. 15

patients it is necessary to use the Milwaukee Brace, a pre-operative localiser cast, surgical instrumentation (e.g. Harrington Rod) with ligament release on the concave side, spinal fusion, and then a localiser-post-operative-cast. Risser and Norquist (1958) explain the working of their devices stating that the forces used in the correction of scoliosis by means of the Turnbuckle cast, (refer Fig. 12) are:

(1) Head and pelvic traction (parallel traction), which corrects angulation between the vertebrae involved in the curvature and (2) Lateral bending of the spine, which corrects rotation of the apical vertebrae. With the anteroposterior hinges of the jacket placed eccentrically over the apex of the curvature, both forces are utilized. Greater traction and less lateral bending are obtained when the hinges are placed more laterally away from the mid-line. Because of the severe lateral bending of the trunk produced during correction in the turnbuckle cast, walking is difficult.

Note the points of traction in both types of plaster casts (refer Fig. 11,12) are against the iliac crest and the mandible. It is apparent that the iliac crest is stable, while the mandible and tempro-mandibular joints are allowed some freedom for function, though limited. This must place some suspicion on the benefits of the mandible and tempro-mandibular joints as positive distraction areas.

Could the facial deformities that arise from such plaster jackets (Hodges, et al 1965) be due to:

(a) Gravity of head resting in the mandibular assembly?

(b) Pressure due to opening and normal physiological function of the mandible pressing against the mandibular assembly?

or (c) as the orthopaedic surgeons suggest, due to distraction of the plaster jacket?

A second method of correction of scoliosis makes use of the localizer cast. The term localizer is used to emphasise the third force used in the correction of scoliosis. This is obtained by pressure over the prominent posterior rib deformity which develops on the side of the convexity of the curve. Postero-lateral pressure applied to this rib prominence produces a corrective force through the ribs in the plane of the curve. This corrective force is, therefore, more efficient and less lateral bending is required than with the Turnbuckle cast.

The results obtained by Risser and Norquist showed the Turnbuckle Cast to produce slightly greater average corrections than the localizer Cast (two to five degrees). It was also pointed out that the amount of correction obtained was between five and ten degrees. A complication of such conservative methods of treatment is prolonged pressure on the ilium and mandible. Goldstein (1966) states, malocclusion deformities may be especially trouble-some in patients treated for a prolonged period in apparatus such as a Turn-buckle and localizer Cast, or Milwaukee Brace, in which pressure is exerted on the jaw.

He further states that when a malocclusion is already present, progression of the occlusal deformity during treatment can be expected unless specific corrective measures are taken.

Howard, as early as 1926 recorded severe facial alterations and gross malocclusions caused by plaster jackets. He maintained that it was the weight of the head augmented by muscle pull producing an almost constant upward pressure upon the lower border of the mandible. He noticed there was infra-occlusion of the molars and premolars, flaring of the maxillary teeth, and reduced facial height. Howard proposed that such plaster braces may be used in the treatment of open bite malocclusions.

Collins and Ponseti (1969) made a follow up study on 215 Idiopathic Scoliotic patients, many of whom had body braces and exercises during adolescence. No patient had surgical treatment. They found curves had increased nine degrees after skeletal maturity, the curves of less than 31 degrees did not increase. The highest average increase was seen in the thoracic curves measuring 60-80 degrees at maturity. Most patients led normally active and productive lives and engaged in activities little different from those of the normal population. This indicates that when Scoliosis is corrected, and not treated surgically to fuse the vertebrae, some form of relapse is almost certain. Risser (1964) states that correction of mild beginning lumbar and thoraco-lumbar curves can be accomplished by a corrective holding cast without fusion, if the holding jacket is worn until the completion of vertebral growth. Maintenance of the correction depends the amount of over-correction and the amount of vertebral growth remaining.

Risser also observed, in a series of over 200 untreated Scoliotics, a gradual increase in the deformity of 8-15 degrees, believing this is possibly due to degenerative changes in the spine.

Arkin (1964), in the use of plaster jackets to reduce structural changes brought about by Scoliosis, arrived at the following conclusions:

(a) Slow prolonged correction by wedging plaster jackets in recumbency can reverse some Idiopathic and paralytic curves completely.

(b) If the curvature can be reversed and maintained in this position, wedging and rotation may be reversed.

(c) When corrective jackets are removed and the patients are allowed to be upright, the original curvature promptly recurs, even though the correction of wedging and rotation may persist in some degree.

Risser further points out that the forces produced by corrective plaster jackets are not effective unless the overwhelming compression of gravity is removed by recumbency.

(ii) Correction and Fusion

The four methods commonly used in pre-operative correction of Scoliosis listed by James (1967) (P.197) are:-

(a) Localizer jacket.

(b) Hinging jacket.

(c) Distraction jacket.
Milwaukee Brace.
Halo-Pelvic, Halo-Femoral Traction.

(d) Harrington Rod.

The localizer jacket and hinging jacket have been discussed under Conservative Treatment. The plaster distraction jacket is similar to the hinging jacket. It has plaster pelvic and cervical elements as in the localizer jacket, but it is elongated vertically by bottle screws on each side. The Milwaukee Brace will be described in the following section.

Halo-traction was first introduced by Perry and Nickel in 1959 to stablise the collapsing spines of patients paralysed by poliomyelitis and now an improved method of application is shown by Pieron and Welphy (1970). The Halo apparatus consists of a head ring, mounting brackets, overhead support, suspension assembly, skull pins, and lock nuts. Methods of counter-traction are achieved by fixing the suspension onto a body plaster, or by placing femoral pins or metal buttons onto the ilium, or in combination with the Milwaukee Brace. (Fig. 15, 16.)

It can be seen that the Halo-pelvic traction by-passes the mandible as one of the main distraction points. The mandible is completely free, whereas in the Risser and Turnbuckle Casts and Milwaukee Brace, the mandible is restricted in its normal function. Alterations to facial and dental structures, as a result of pressure from these orthopaedic appliances has been well documented. (Alexander 1966) (Hodges, et al. 1965).

Therefore, one decided advantage of the Halo-apparatus as a means of traction, is that it allows normal physiological function of the mandible, at the same time using the cranium as a more positive point of traction.

Winter, et al (1968) indicates the most common technique used in spinal fusion is the Moe-facet-fusion technique which is usually performed with the addition of autogenous iliac bone in patients old enough to supply such bone.

Results of fusion are shown by Moe (1958), on 130 patients treated by three fusion techniques. The average gain in correction was 40 per cent. Patients with pseudoarthroses showed an average gain of 22 per cent. Moe concludes that correction and fusion of the scoliotic spine is satisfactory cosmetically and functionally, provided that the proper fusion area is selected and the graft becomes solid and mature.

(iii) Surgical

Numerous methods of surgical correction of the spine have been tried. Allan (1955) reports the forceable correction of a curve by means of an expanding device or jack. The correction is obtained by expanding the concave side, under surgery. The jack is placed between the transverse processes of the vertebrae at the top and bottom of the major curve. Allan reports corrections between six and sixty degrees.

Roaf (1963), working on the hypothesis that scoliosis is initiated by vertabral growth disturbances, used surgical correction by hump resection and costo-vertebral joint removal. His idea was to reduce the deformity, and to arrest growth on the convex side of the curve. He shows in 188 patients, 44 had improved 20 degrees or more, 69 by 10-19 degrees, 75 less than 10 degrees.

These findings indicate that growth disturbances of the vertebrae may not play such an important role in the aetiology of scoliosis which is also

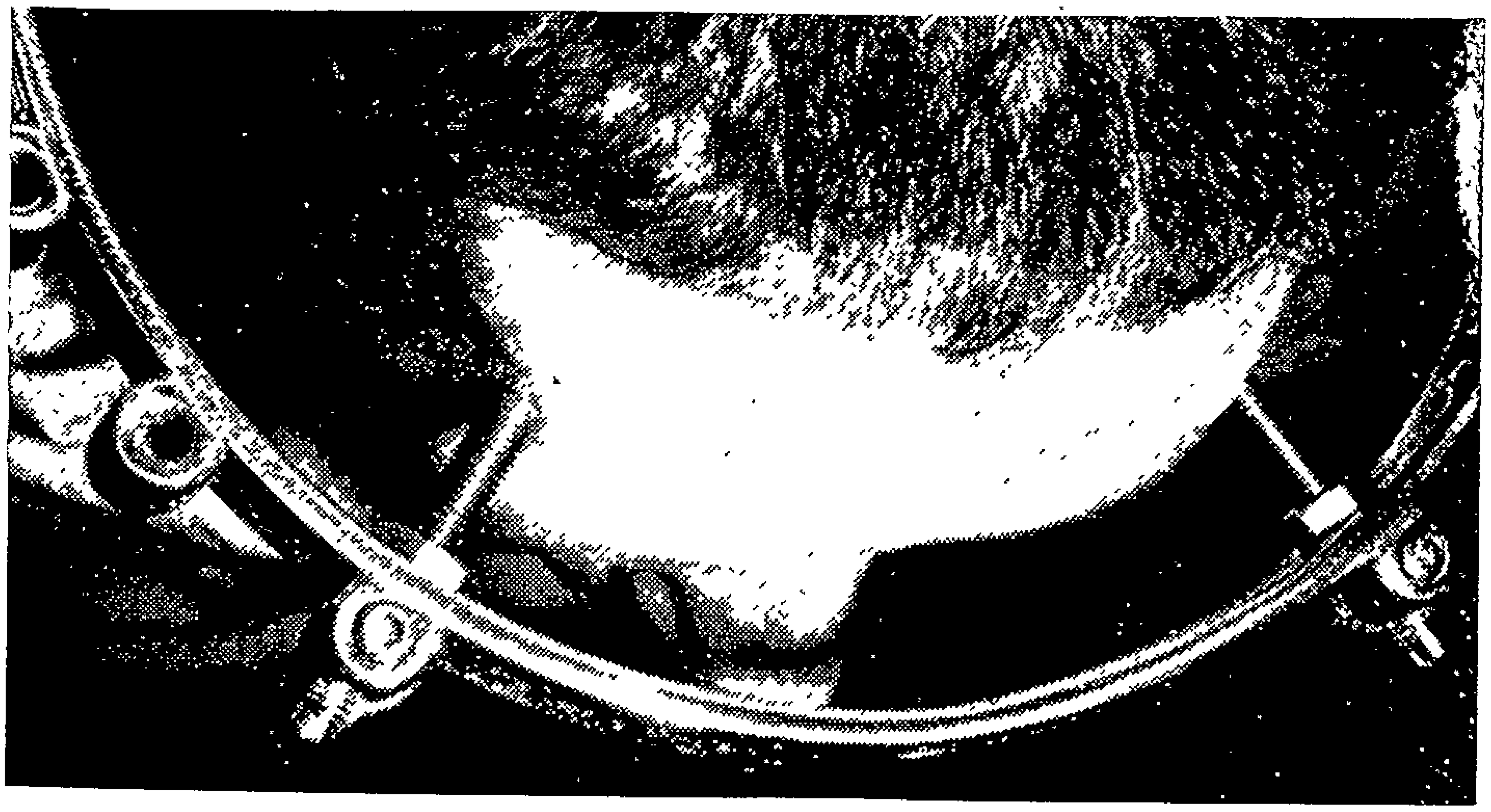


Fig. 16

A Halo showing the head ring attached by screws direct to the cranium. *(From Pieron and Welphy 1970, P.121)*

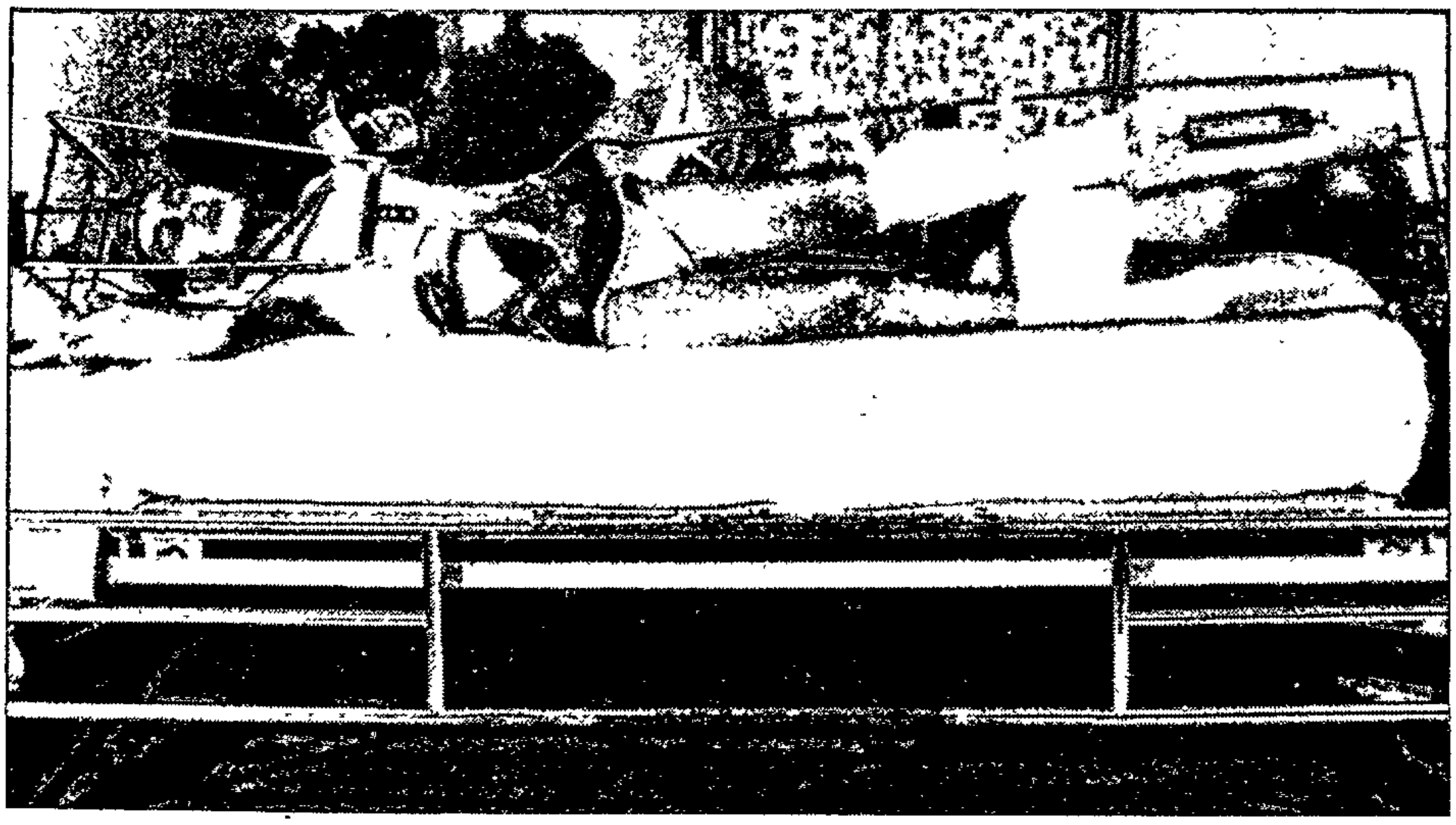


Fig. 17

The Milwaukee Brace incorporating the halo apparatus. Note traction is applied to the right side only. The plastered leg is attached to a spring scale which in turn is attached to a weight. *(From Schmidt 1971, P. 74)* indicated by the work of Michelsson (1965) who shows that in scoliosis in pigs it is the concave side that grows most not the convex that Roaf supposed.

One of the most common means of surgical correction is the Harrington Rod method, (Harrington 1962). Metal rods with a ratchet system and hooks are attached to vertebrae, allow for progressive distraction of the curve. Wilson, et al (1971) using this technique on 67 patients found curve correction usually better than 50 per cent.

Goldstein (1969) using a combination of bone grafting and Harrington Rod fixation for treatment of scoliosis, had corrections between 40-60 per cent.

Other methods of surgical correction are:

(a) Wedge resection (Goldstein, 1966).

(b) Growth control in the form of stapling on the convex side, (Nachalas and Borden, 1951).

5. THE MILWAUKEE BRACE

This brace was first described by Blount in 1944 and later a slightly modified form of this brace was presented by Blount and Schmidt (1958). They describe the brace as consisting of the following components: A pelvic girdle which rides over the tops of the iliac crests, overlapping vertical bars and a mandibulo-occipital assembly. (Figs. 14, 15, 16.)

Blount, et al (1958) explains that the brace was developed as a refinement of the distraction or transection plaster jacket, to be used in the operative treatment of Scoliosis.

James (1967) (P.171) describes the Milwaukee Brace as the only brace which can effectively stretch the child. The design allows controlled distraction between the pelvic girdle and the mandibulo-occipital assembly. The child is kept permanently stretched and the effect of gravity partially avoided.

(i) Construction

The following method of construction is that employed at the Royal Prince Alfred Hospital, Sydney. It is similar to the method used by Blount and Schmidt, (1958) and modified by Harrington.

The patient is hung by a halter under the occiput and mandible, being suspended by his own weight. The torso is steadied by a metal frame while the cast is made. A plaster impression, using wet plaster bandage is taken of the iliac crests, thorax, back, chin and occiput. When the plaster has set it is cut up the centre, prized apart and the patient rotated sideways out of it, (Figs. 18, 19, 20). From this negative mould a positive plaster cast is made. The cast is then trimmed to allow the pelvic girdle to be seated firmly over the iliac crests. The pelvic girdle is now moulded into position using soaked leather. (Figs. 21, 22, 23.) The leather is reinforced by 1 inch x $1\frac{1}{16}$ inch metal strips which are made to fit the contours of the pelvis. These metal

Fig. 18

Patient is hung by the halter and is stabilised by the metal frame. The pelvic plaster is adapted. A rubber strip to allow separation is placed between the thorax and plaster.

Figs. 19 and 20. Show the completion of the back and thoracic plaster. Note the moulding in and over the iliac crests, behind the occiput, and under the mandible.

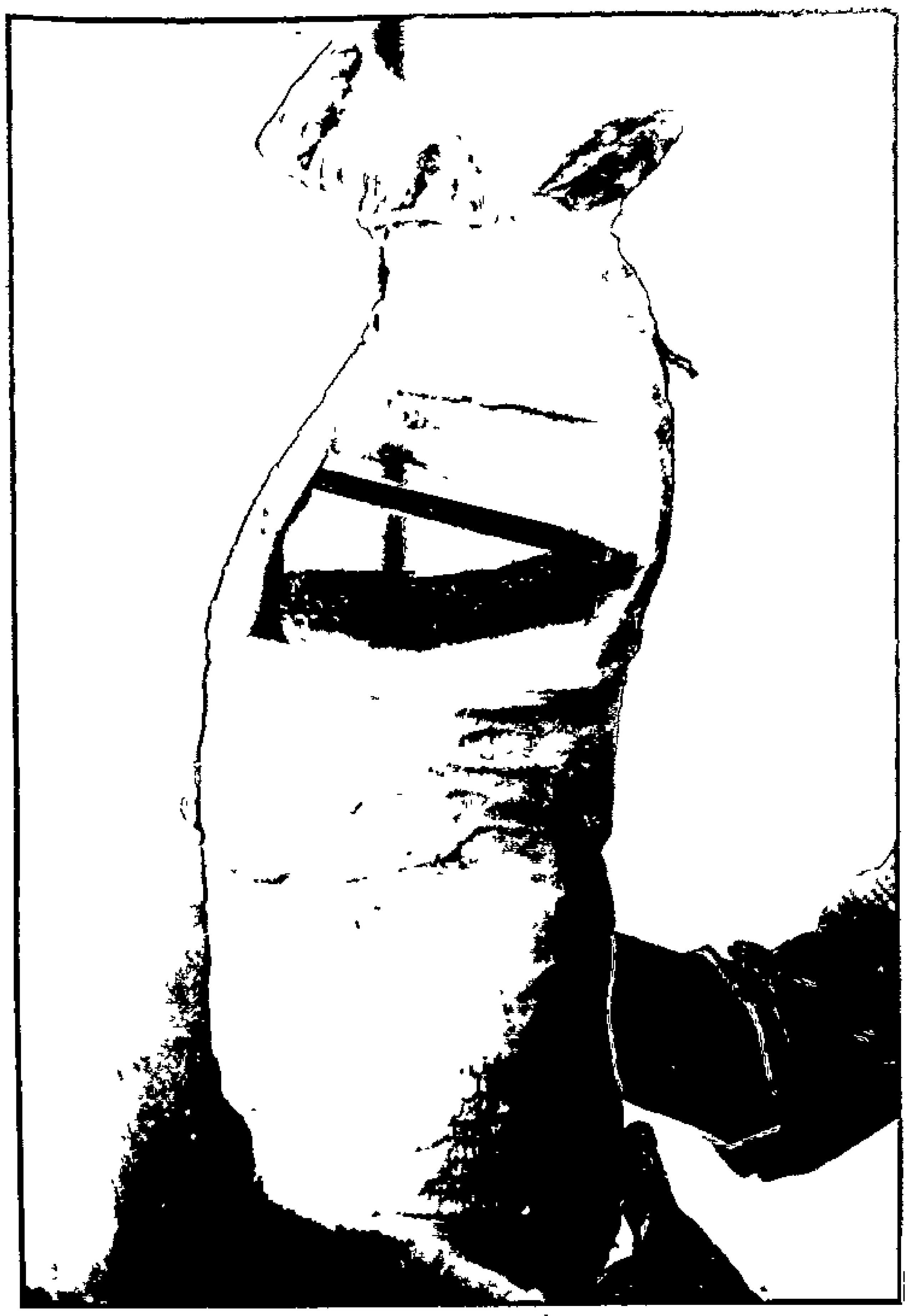


Fig. 21

Binding together of the plaster segments to form the negative mould.

Fig. 22

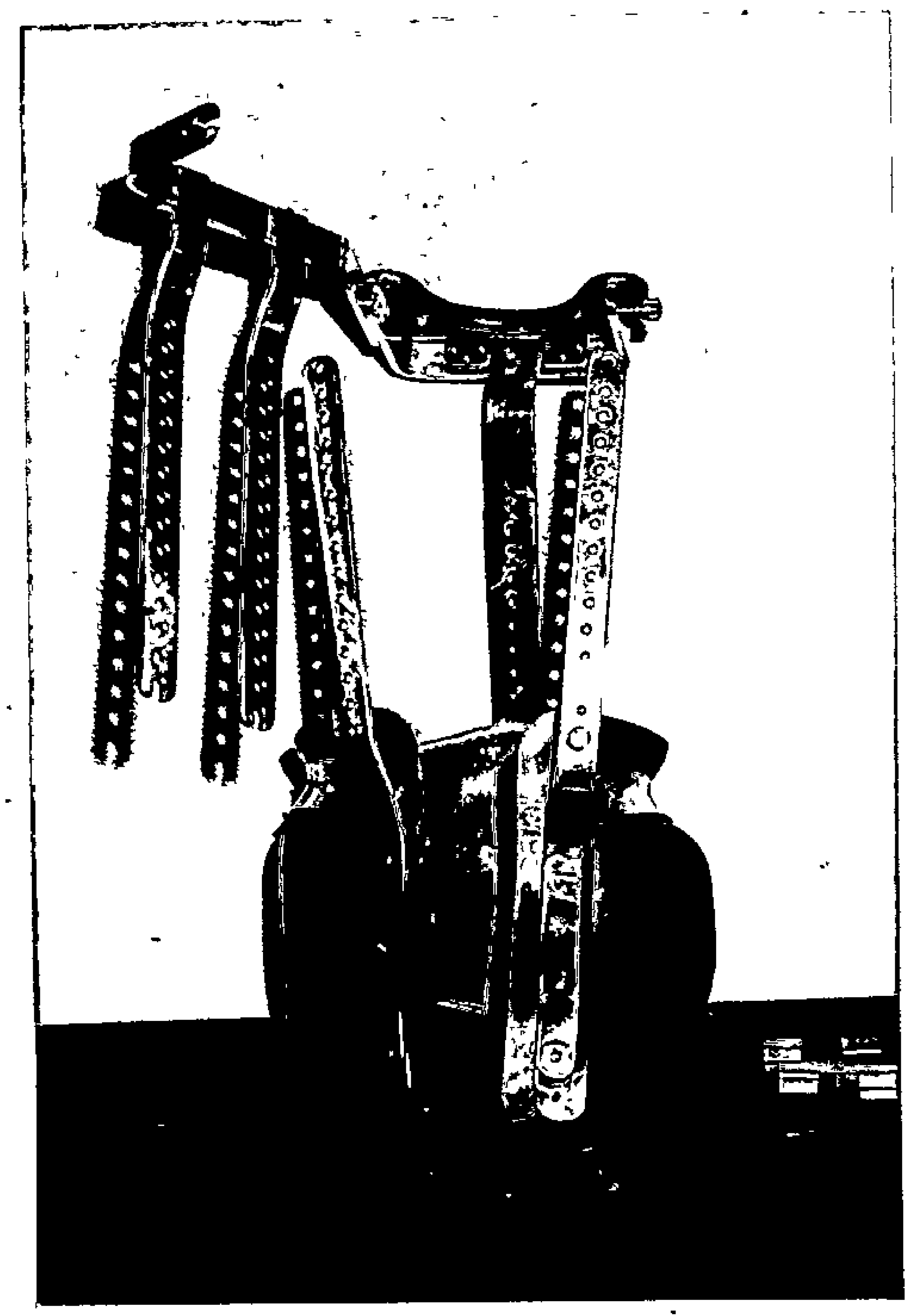


Fig. 23

Fig. 22 On the right the positive plaster cast with the pelvic area covered in soaked leather. On the left the completed Milwaukee Brace minus occipital pad.

Fig. 23. The posterior aspect of the Milwaukee Brace.

strips are attached infront by hinges to allow easy fitting and removal of the brace.

The anterior vertical bar consists of $1\frac{1}{2}$ inch x $\frac{1}{4}$ inch aluminium. The two posterior bars are made from $\frac{1}{4}$ inch x $3\frac{3}{16}$ inch aluminum. The bars are slotted and tapped to allow for progressive distraction by adjustment.

The mandibulo - occipital assembly consists of several parts: two oval reinforced leather pads for the occiput, and a flattened reinforced leather horseshoe shaped pad for the mandibular platform. These are connected by two metal strips which are in turn connected to the vertical bars. Blount and Schmidt (1958) maintain the use of a lateral pressure pads direct to the convexity of primary curvature. Further, in those with low curves, a pressure pad is applied at the site of the convexity to be combined with a narrow sling at the opposite axilla to give counter pressure against the ribs.

Fitting and Milwaukee Brace Mechanism

Blount and Schmidt (1958) explain the brace should fit loosely with only slight corrective force, till the patient becomes accustomed to it. The patient should be able to raise his chin and occiput simultaneously from the head pads. Further, the appearance of pressure areas is evidence that too much force is being used. The chin must be capable of protrusion at any time and pain in the temporomandilbular joint, or pain in the teeth, means the brace must be shortened.

The design of the brace almost explains its mechanism in that as the patient grows and is stretched the distraction rods are placed up another notch, using the criteria that you should be able to place two finger widths between the chin and the mandibular pad. (Fig. 24)

(ii) Indications for use of the Milwaukee Brace.

Blount, et al (1958) maintain that the Milwaukee Brace should be used for three clearly defined situations:

Fig. 24

Shows the two finger widths between chin and chin pad used as criteria for fitting and adjusting the Milwaukee Brace.

(a) When the existing idiopathic deformity is still acceptable in an adolescent, near the end of the growth period , a rapidly progressive curve may sometimes be reduced 25 per cent or more and held until growth is completed.

(b) In a few convalescent poliomyelitic patients with functional or very early structural scoliosis, the Milwaukee Brace has aided in reducing the curve and holding it in check until muscle balance has been re-established.

(c) In patients with chronic poliomyelitis and abdominal weakness , the brace has been found most efficient in the conservative treatment of scoliosis combined with pelvic obliquity.

James (1967)(P. 183) reports his indications for use of the Milwaukee Brace as

. The control of scoliosis in patients too young for spinal fusion.

. Control of scoliosis in the adolescent who develop near the end of growth, when it is used to avoid surgery.

Moe (1971) indicates the Milwaukee Brace may be used with benefit in scoliosis of nearly all aetiologies. Its greatest benefit is to the juvenile and adolescent variety of Idiopathic Scoliosis with moderate or small , slightly-structural curves. Those discovered during growth it will give excellant permanent correction of structural curves of 40 degrees or less. Moe lists contraindications of the brace for single major curves of 60 degrees or more in the older adolescent. Also the Milwaukee Brace does not lend itself to effective control of Paralytic Scoliosis associated with pelvic obliquity.

It is noticeable that the indications for use of the Milwaukee Brace have changed from Blount and Schmidt in 1958, who believed that the Brace had limited use, to a more purposeful role in the hands of Moe 1971. This could be due to the fact that in 1958 the brace was untried and that now it has had many modifications. It may be possible in the future that further modifications will lead to an increase use of the Milwaukee Brace in the correction of Scoliosis.

The Milwaukee Brace also plays an important roll in post surgical inmobolization. (Goldstein 1971).

(iii) Results of Treatment. James (1967)(P.180), reporting on 57 cases of scoliosis with varing aetiologies, found that 43 patients showed significant improvement of their scoliosis whilst in the brace. Only three patients had a deterioration of their curves during therapy and in none of these was the progression over 12 degrees.

Moe and Kettleson (1970), publishing work on 132 Milwaukee Brace - treated patients listed the following results.

(a) Best correction was obtained within the first twenty - five months in 97 per cent and within two and one half years in all patients.

(b) In high Thoracic curves, median brace correction was 17 per cent; at the completion of brace wearing the median was ten per cent.

In Thoracic curves, median brace correction was 38 per cent; when the brace was discontinued this dropped to 24 per cent.

In Lumbar curves, median brace correction was 55 per cent when the brace was discontinued it was 23 per cent.

(c) The best responce to brace therapy occured when treatment was begun before the iliac epiphysis was capped.

(d) Long curves corrected best.

(e) Some of the larger (45 to 50 degrees) double major curves of the right thoracic left lumbar variety showed no roentgenographic improvement, but still demonstrated substantial cosmetic improvement with better balance and lessening of the rib prominence.

(f) The best results were obtained when there was full co-operation with the patient.

Goldstein (1971) points out that, over the last three years as a result of Milwaukee Brace treatment in the initial stages of Idiopathic Scoliosis the number of patients requiring surgery have been reduced significantly, perhaps 50 per cent.

As Goldstein indicates, the encouraging results of the Milwaukee Brace have resulted in an increase use of this appliance. It has, however, resulted in deleterious effects particularly to the facial structures. This is evidenced by at least a twenty fold increase in the orthodontic literature on the effects of the Milwaukee Brace on the jaws and teeth, over the previous five years.

6. EFFECTS OF THE MILWAUKEE BRACE ON FACIO-MAXILLARY STRUCTURES.

Blount, et al (1958) states that prolonged use of the Milwaukee Brace will sometimes give rise to malocclusion and prominence of the upper incisor and canine teeth, but that this was a small correctable price to pay in exchange for the prevention of a severe scoliosis. In modification of the brace, Blount later changed to a padded mandibular support which permitted free protrusion of the jaw and maintained that this did not lead to an increased overbite.

It will be apparent from the following findings that the Milwaukee Brace can have a severely adverse effect on the maxillo-facial structures. The questions that should be kept in mind during this discussion are;

- Would the brace be more effective if some locking of the occlusion is possible, thus making the mandible a more stable pressure area as the iliac crest is?

- Wouldn't the prevention of severe malocclusions be more desirable if only on psychological grounds, in the ever-so-common pubescent scoliotic female?

In the past five years numerous people have recorded the effects of the Milwaukee Brace on the facio-maxillary structures. Alexander (1966), Luedtke (1970). Lindskog (1967), Cruber and Earle (1969), have recorded significant findings:

The following are a list of observations that were common.

(i) Dental Changes

(a) Increase in overbite.

(b) Protrusion of upper and lower teeth with concomitant spacing.

(c) Movement of molars buccally and pre-molars buccally and mesially.

(d) Resorption of alveolar processes.

(e) Closure of open bites.

(f) Depression of maxillary and mandibular molars and premolars.

Fig. 25

Fig. 26

Figs. 25, 26, 27.

Intraoral changes as a result of Milwaukee Brace therapy after four years.

Patient M.C.

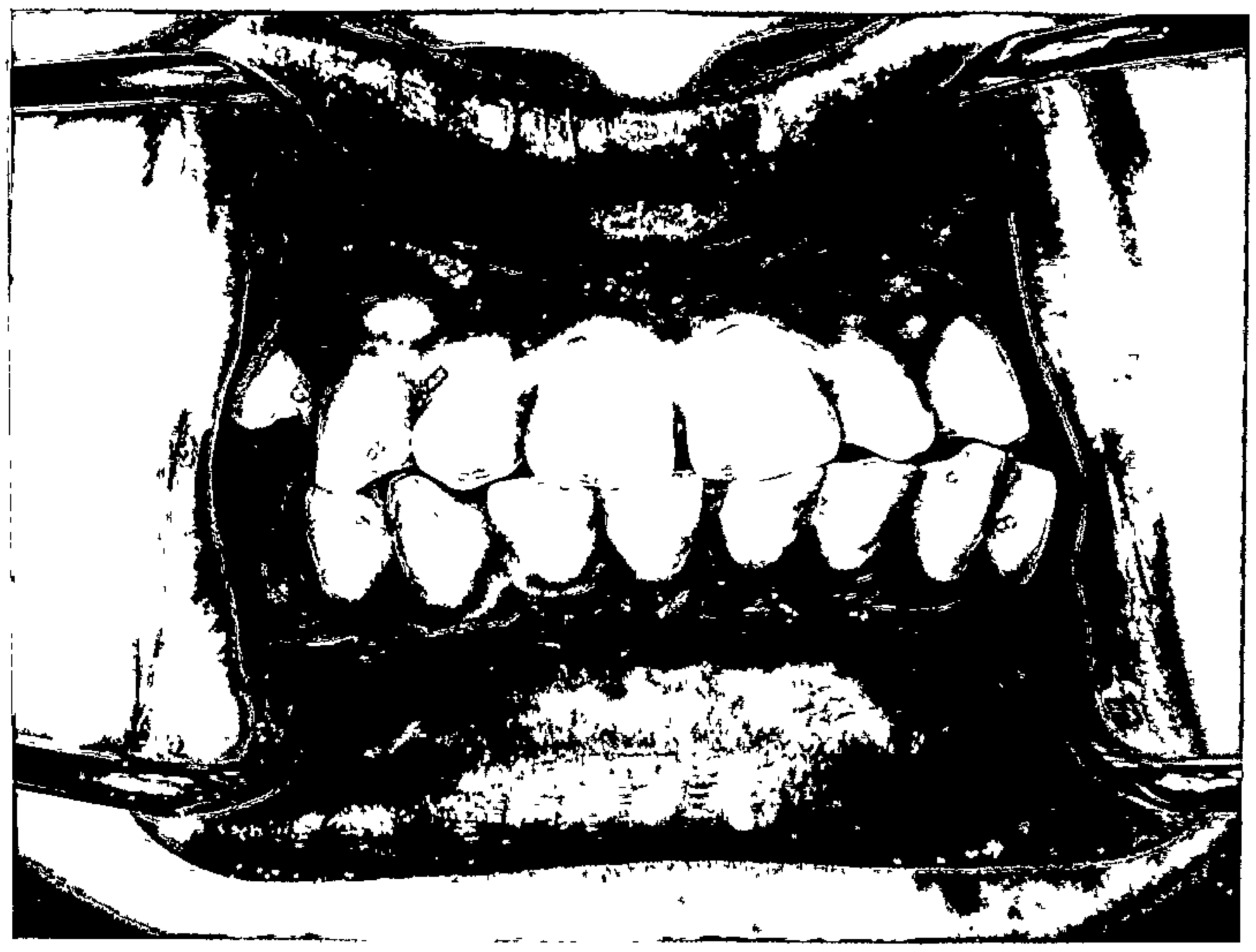


Fig. 27

Fig. 28

Traumatised palatal tissue from excessive deep bite plus spacing and mobility of upper anterior teeth, as a result of one year Milwaukee Brace therapy, Patient M.M.

Fig. 29

Anterior view of the above patient showing spacing and displacement of upper anteriors, collapse of lower anteriors and deep overbite, Patient M.M.

(ii) Mandibular changes (Fig. 30)

(a) Increased bone apposition at gonial angle.

(b) Resorption and flattening of the lower border where the mandibular pad contacts the jaw.

(c) Antegonial notching.

(d) Decrease mandibular plane angle.

(e) Counter clockwise mandibular rotation.

(f) Possible redirection and/or inhibition of mandibular growth.

(g) Decrease in gonial angle.

(iii) Facial Changes (Fig. 30, 31, 32)

(a) Reduction in facial height.

(b) Elevation of the palatal vault and flattening of the palatal plane.

(c) Redirection of normal downward and forward sutural growth of the face.

(d) Counter clockwise rotation of the maxilla.

(e) Soft tissue change in form of cherub face.

Alexander, (1966) records the first sign that the pressure from the mandibular pad is affecting the jaw is sore and hypersensitive teeth. The teeth may be mobile, particularly the anteriors.

Logan, (1962) believed the increase in overbite is due to sinking of the molar teeth into alveolar bone, and if this effect continues there is produced a proclination of upper and lower incisors, and also a tendency for the upper and lower molars to incline buccally. As these displacements progress, the soft tissues of the lip and tongue contribute to the proclination. An interesting observation from Logan was that the canines tended to move only slightly buccally but not to decrease their height in any way.

Histologic proof that the molars are depressed is shown by Cutler, et al (1972), on histological examination of the molars of Macaca Mulatta monkeys

Fig. 30

Cephalometric radiograph of patient M.C. showing severe flattening of the lower border of the mandible, intrusion and flaring of teeth, and compression of the lower facial structures.

Fig 31

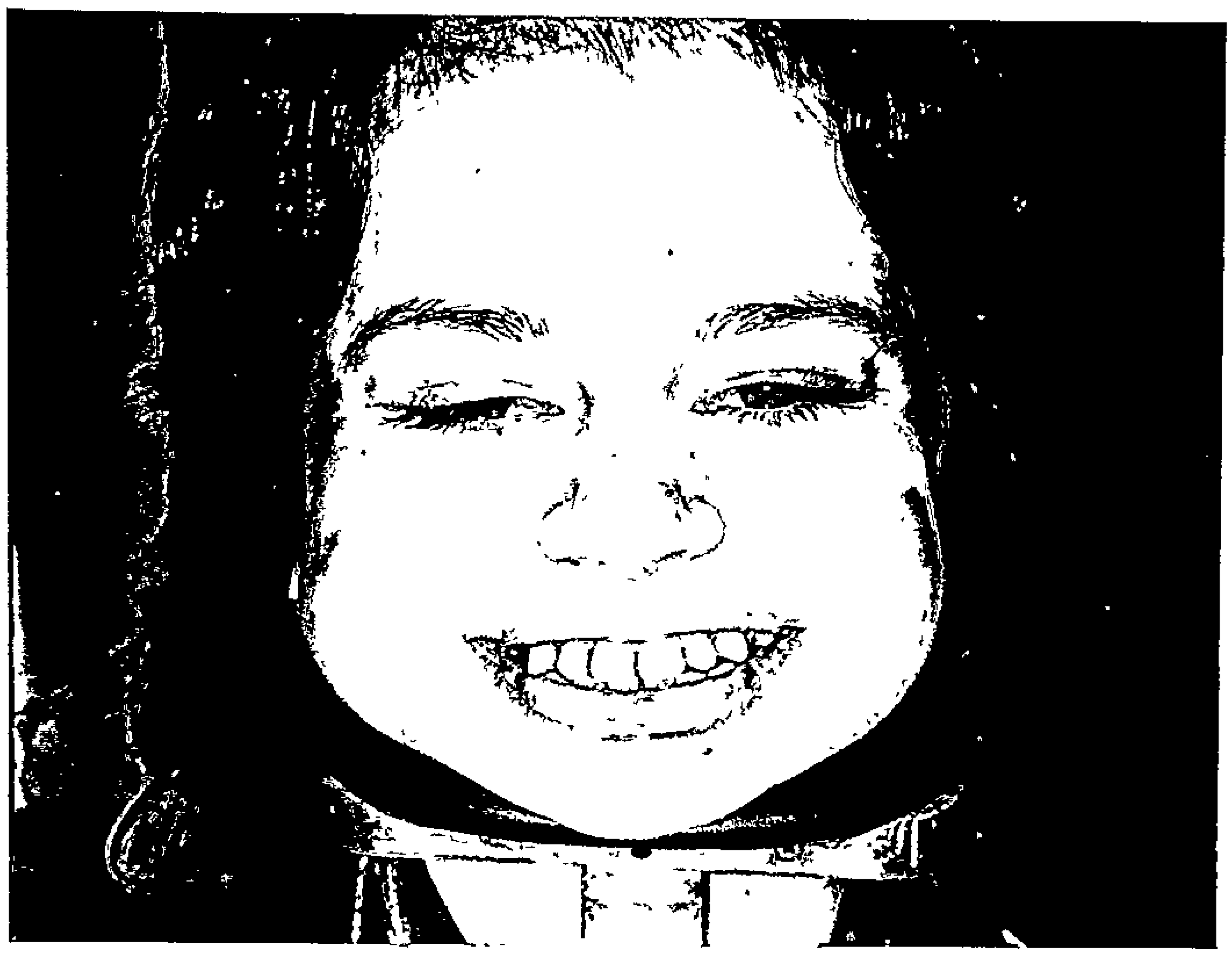


Fig 32

Figs. 31 and 32 show the soft tissue changes in Milwaukee Brace patient M.C., typical is the rounded face appearance after long term brace therapy.

which wore a Milwaukee Brace for varying periods of time. There was active resorption of bone at the apices of several teeth.

James (1967) (P. 177) describing the effect of the Milwaukee Brace on facial structures, explains that the alveolar ridges of the maxilla and mandible are the most labile bones in the skull and this is seen clinically by an alteration in the positioning of the teeth. The degree of malocclusion produced varies with the age of the patient and extent and duration of the force applied.

The following average cephalometric angular measurements taken from seven Scoliosis patients, shows statistically the dental changes after two years Milwaukee Brace therapy. (Alexander 1966):

. Decrease interincisal angle 19.2 degrees.
. Decrease incisomandibular plane angle 10.5 degrees
. Increase upper central to sella nasion 12 degrees
. Decrease mandibular plane to sella nasion 2.5 degrees
. Decrease gonial angle 4.2 degrees.

In Lindskog's cephalometric work on Milwaukee Brace treated scoliotics he came up with the following conclusion on dental changes.

The teeth in his control group reacted to the Milwaukee Brace in a variety of ways, depending upon the types of anterior occlusions. The anterior overbite continued to increase, the protruding incisors flared rapidly, and the open bite occlusions closed because of the intrusion of the posterior teeth. The mandibular teeth showed less resistance to the pressure than did the maxillary, as the lower molars intruded and the incisors extruded. The lower posterior segments in the control group moved mesial to their original position. The maxillary posterior teeth showed little sagittal movement although a few indicated slight distal crown movement.

A significant finding from Rock and Baker (1972) on a group study of the effects of Milwaukee Brace on dento-facial growth was an increase in the angles SNA and SNB. This would no doubt be due to bone remodelling around the upper and lower anterior teeth as they procline.

This also lends support to Duyzings (1969) who believes when the force is strong, both alveolar processes may grow forward. A bimaxillary proclination as well as bimaxillary prognathism with reduced overbite may result.

Howard (1926) also observed that after mandibular immobilisation using a plaster cast, the patient had a severe oral hygiene problem and gingivitis was present. This would be understandable in that the jaws are restricted in movements, which would necessitate the patient adjusting a new method of performing oral hygiene.

7. CHANGES IN MANDIBULAR MORPHOLOGY AND GROWTH PATTERN

It must be kept in mind the distraction pressure of the mandibular assembly acts against the downward forward growing mandible. And the structures through which pressure from the Milwaukee Brace passes are the lower border of the mandible, alveolus, teeth, maxilla, posteriorly the ramus, temporomandibular joint, then remaining cranial bones and sutures. It is the soft, spongy alveolus that collapses and leads to gross alteration of teeth and occlusion initially. Long term effects on the temporomandibular joint, facial bone and cranial sutures are probably more important, yet to this stage, little work has been carried out. It is unknown whether the effects of the brace on these structures are permanent, or reversible. (Alexander 1966)

Characteristic changes observed by Eastham (1971) included resorptive remodelling of bone on the posterior aspect of the condyloid process, bony apposition on the anterior part of this process, heavy bone apposition on the lower part of the posterior border of the ramus, in some cases resorption of the posterior border of the ramus and resorption in the antegonal notch area. Little change was observed on the lower border of the body of the mandible and the symphysis.

Eastham suggests the antegonial notching that occurs in the form of remodelling is due to limited mandibular opening and may be related to change in mandibular muscle function.

Alexander (1966) recorded the gonial angle on all before and after treatment cephalograms with his group of Milwaukee Brace treated Scoliotics. He found a mean decrease of 4.5 degrees with individual measurements varying from 1.5 to 7 degrees. He also noted the gonial notch was more accentuated in the younger patients. Also in some cases, the abnormal lowering of the symphysis in relation to the lower border of the body of the mandible. Alexander suggests this phenomena could be a direct result of the inhibition of growth along the middle to anterior 2/3 of the lower border of the body of the mandible by the mandibular part of the Milwaukee Brace.

Lindskog (1967) in reporting alterations of mandibular growth due to the Milwaukee Brace arrived at similar results to Eastham. However, he did find resorption under the anterior half of the lower border of the body and inferior to the symphysis, resorption being evidenced consistently just anterior to the gonial angle.

Gruber, et al (1969) recorded in some of their Milwaukee Brace patients almost complete resorption of the cortical layer of bone at the inferior border of the mandible. They also recorded, a decrease in height of the ramus, decrease in height of the mandible in the molar and bicuspid area and an increase in horizontal length of the mandible.

Similar findings to Alexander were also made by Thørs (1964). Significant was the apposition, greater than normal on the dorsal part of the ramus. He believed this to be due to compensatory remodelling of the mandible.

The change in morphology of the mandible, Duyzings (1970) explains, is partly due to the fact there is little space between the chin pad and chin, to move the face upwards. The child tries to stretch all the muscles of the floor of the mouth, the muscles to the hyoid bone and to the sternum. The contraction of all these muscles moves the mandible dorsally.

Histological evidence that normal circumferential periosteal apposition that occurs along the lower border of the mandible, is altered by Milwaukee Brace treatment was seen in the form of irregular scalloping, resulting from the presence of Howships lacunae in the Macaca Mulatta group of monkeys. (Cutler, et al. 1972).

(i) Alteration in Mandibular Growth Due to the Milwaukee Brace

There is some argument as to how and what bones have altered growth patterns as a result of Milwaukee Brace treatment.

Thørs (1964) used metal implants to study facial growth of Milwaukee Brace patients, and concluded that the growth alterations produced were the result of 3 types of growth disturbance.

(a) Intrusion of the upper and lower teeth.

(b) Followed by corresponding resorption of the alveolar processes.

(c) Inhibition of growth of the condyles.

On their study of the Macaca Mulatta monkeys, Cutler, et al (1972) stated that the most significant result of brace therapy was the reversal of normal downward and forward growth of the maxilla and mandible. The entire dento-facial complex was displaced in a superior direction. They also recorded a loss in anterior and posterior facial height. They went on to explain that actual inhibition of vertical growth is difficult to prove and suggest in future, this may be assessed by metal implant markers in the temporomandibular joint.

Histologically, they did show evidence of remodelling on the posterior articular surface of the condyle, but no degenerative changes are produced in the temporomandibular joint by pressure from the modified Milwaukee Brace. They concluded that histological and radiological evidence suggests that condylar growth is retarded by pressure from the brace.

Alexander (1966) recorded a decrease in distance between articulare to gonion. He believed the mandibular condyle was being pushed superio-posteriorly into the glenoid fossa, pointing out that what is actually occurring in this area can only be assumed. The possibilities are:

(a) Compression of the soft tissues in the temporomandibular joint area;

(b) Slipping forward of the articular disc with the head of the condyle resting directly on the posterior portion of the glenoid fossa;

(c) Resorption of the articular disc;

(d) Posterior-superior resorption of the glenoid fossa;

(e) Resorption of the head of the condyle;

(f) A combination of any of these.

Severe changes in temporomandibular joint structures were reported by Ostowski (1968). In one of his patients he records a 7 degree change in positioning of the temporomandibular joint as a result of Mulwaukee Brace therapy.

Eastham (1971) reported that in no instance in his study was there resorption or shortening of the condyloid process or head of the condyle. He further pointed out that decrease in ramus height observed by Alexander, may well have been due to resorption of the lower border of the ramus and not a change in the temporomandibular joint area.

Lindskog (1967) and Thørs (1964) believe there is inhibition of condylar growth, and possibly condylar remodelling.

(ii) Facial Changes

Thørs (1964) believed the reduction in facial height was due to

- Intrusion of teeth of both jaws.
- Bodily displacement of the Maxilla superiorly.

Gee (1970) records that during brace therapy, the vertical development of the face stopped in all his patients. After the brace was removed, some vertical dimension was regained.

No change in upper anterior face height was recorded by Alexander (1966), the linear measurement being taken from the Anterior Nasal Spine to the Nasion. The greatest amount of loss in anterior face height (i.e. Nasion, N, to Gnathion Gn) was found in the lower face. (ANS to Gn). Further, the upper molars demonstrated slight depression, but a greater amount of depression was found in lower molars. Also noticeable was the reduction in lower posterior face height (i.e. Articulare to Gonion).

Alexander goes on to list statistical data comparing the changes in measurements in before-and after- treatment tracings of all fourteen Milwaukee Brace patients, showing facial changes.

MEAN MEASUREMENTS	BEFORE	AFTER
Total anterior Face Height in mm.	128	107
Upper anterior Face Height in mm.	50.2	50.3
Lower anterior Face Height in mm.	61.9	56.9
Lower posterior Face Height in mm.	42.1	37.3

It appears then that it is mainly the collapse of the lower anterior face height that leads to the cherub face seen in brace patients. The question that remains unanswered in literature is the relationship which this shortening has to the orofacial musculature.

Though Alexander shows both absence of, and increase in, upper anterior face height, many authors have found the maxilla in fact moves superiorly. Cutler (1972), using metal implants noticed the mandible had moved in both an upward and forward direction, the mandibular change being twice as great as the maxilla.

Eastham (1971) put the loss of vertical growth down to:

(a) Sutural adjustment allowing movement of the maxilla upward and forward with counter-clockwise rotation.

(b) Upward and forward movement and counter-clockwise rotation of the mandible.

(c) Mandibular remodelling, including heavy deposition at the posterior border of the ramus, and redirected growth at the head and neck of the condyle upward and forward, affecting, therefore, a reduction in the mandibular angle.

(d) Only partial inhibition of vertical growth of the head of the condyle, since in most cases upward and forward growth was demonstrated.

(e) In almost all cases, growth of the condyle was expressed horizontally relative to anterior cranial base.

(f) Intrusion and forward movement of upper and lower posterior teeth associated with changes in incisor inclination, including overbite deepening.

Thørs (1964) showed reduction in the upper face by measuring the distance from nasion to the implants in the maxilla, superimposing before and after cephalometric tracings of his Milwaukee Brace patients. He believed this to show clear evidence of compression of the sutures of the upper face as a change of direction in growth in them.

8. OTHER SIGNIFICANT CHANGES

(i) Oral Cavity

Gruber, et al (1969) recorded a decrease in the space in the floor of the mouth for the tongue, flattening and decrease in palatal vault, and, in some cases, deepening of the voice after Milwaukee Brace therapy. However, voice change could be a maturational effect.

Alexander (1966) noted the oral cavity in his group of Milwaukee Brace patients, was reduced in size giving the effect of an enlarged tongue. The patients had much difficulty in pronouncing words and they developed a nasal twang, and both groups (control and experimental patients) developed deeper and heavier sounding breathing than normal.

It seems then that flaring of the teeth, with concomittant loss in oral cavity space and speech difficulty are normally part of the result of long term treatment in the Milwaukee Brace.

Little work has yet been done on the other pressure areas. Galante, et al (1969) however, noted that the Milwaukee Brace does cause pelvic deformities as well as mandibular deformities. They suggest that new points of support should be defined and their relative efficiency evaluated.

(ii) Growth Sutures

Thørs noted compression of the sutures of the upper face (1964), also recording the following departures from normal growth pattern.

- Periosteal resorption of the nasal cavity and
- Normal periosteal apposition on the dorsal surface of the maxilla and on the maxillary tuberosity.

Histologically Cutler, et al (1972) showed the frontomaxillary suture under compression from the brace exhibited predominantly resorptive activity, also showing resorption of the outer cortical plate of the occipital bone and deposition in the adjoining lambdoidal suture.

Changes in the nasomaxillary structures recorded by Jansen and Bluker (1965), due to restrictive orthopaedic force on the mandible in Macaca Mulatta resulted in the tip of the nasal bone, Point A, and Prosthion moving in an upward forward direction, this probably being due to the transmission of the vertical component of force via occluding teeth.

9. CHANGES IN DENTO-FACIAL STRUCTURES AFTER REMOVAL OF THE MILWAUKEE BRACE.

Prior to recent comprehensive work on the effects on the dentition and facial structures, due to the Milwaukee Brace, orthopaedic surgeons recorded that these structures returned almost to normal on the removal of the brace. James (1967)(P.177) explains that the undershot jaw appearance is due to change in the teeth, not in the mandible. We know from evidence presented that this is not the case. It is due to inhibition of condylar growth, resorption from the lower border of the mandible, reduction in size of the alveolus and angulation of the teeth.

Also, the claim of the return of severe malocclusions to almost complete normality is without supporting evidence. It depends what the individual observer decides is normal.

In more recent work, Cutler, et al (1972) noticed on brace removal, resumption of condylar growth and appositional growth on those surfaces of the mandible which had undergone resorption. Also, the dentition tended to return to normal and, in general, there was a complete reversal change noted after brace therapy. Logan, (1962) observed, after brace therapy, a spontaneous decrease in overbite and repositioning of the teeth.

Hodges (1965) recorded, one year after brace therapy, that the dentition showed maximum recovery, believing the duration of jaw immobilisation was more important than any other factor. In 106 cases studied, 85 per cent regained an acceptable position and appearance.

The question arises as to what amount of permanent damage is done to the facio-maxillary structures, as a result of long term use of the Milwaukee Brace. Because of the prolonged nature of studies involving Milwaukee Brace, the question is not fully answered.

Howard as early as 1929, records at the end of 12 months after plaster cast immobilisation, there was only a slight tendency for the malocclusion to relapse to its original state while the soft tissue showed marked improvement.

In the use of the Milwaukee Brace, Logan, (1962) Cutler, et al (1972), Gee (1970) noticed how the soft and hard tissue of the faciomaxillary structures tended to return to normal. Logan believed that it was not possible at this stage to say whether changes are completely reversible.

Wright (1972) states that"after the Milwaukee Brace removal there may be some spontaneous correction in the deformities. Occasionally, the anterior teeth undergo some self-correction resulting in a slight improvement in vertical dimension. Unfortunately, this reversal is slight and orthodontic treatment is required to restore the patient to a better occlusion and facial profile."

The reason for this sudden growth in bone and alignment of teeth in the most part, is still unknown. It is remarkable in that, prior to brace removal, deformities to facial structures and occlusion, in some cases, are extremely severe. It is as though these structures had some kind of elastic memory.

Evidence that facial musculature does return teeth to a more stable position when displaced is shown by Attaway (1962). Buccally modified premolars by means of gold inlays tended to be pushed lingually and lingually modified upper premolars tended to move buccally.

Thus the apparent return to normal of proclined teeth due to the Milwaukee Brace is in part at least, due to the orofacial musculature.

That growth can have little effect on this recovery is claimed by Logan (1968). He superimposed cephalometric tracings before and after Milwaukee Brace therapy to see what amount of recovery occurred. He states,

> "The mandibular position had changed. The condyle, which was apparently located upwards and forwards, had moved downwards and distally.

While the distal surface of the condyle had moved some 2mm distally, the distal surface of the angle had moved 5mm forward. This is an absolute shift in mandibular position to which growth can have contributed little. The mandibular angle which was considered immutable had increased no less than 10 degrees from 64 degrees to 74 degrees, this being an alteration in the shape of the basal bone."

10. FORCES EXERTED BY THE MILWAUKEE BRACE

The controversial problem of whether the brace itself exerts pressure on the facio-maxillary structures, thus causing deformities, or whether the weight of the head resting in the brace causes these changes, is still unsolved.

Blount (1958), originator of the brace, maintains the aim of the brace is to make the patient stretch so that it is the muscle pull on the spinal deformity that causes the spine to straighten. Blount claimed that the brace exerted no actual pressure on the skull. Support for Blount's theory is evidenced in fitting the brace, which is allowed 1 to $1\frac{1}{2}$ inches between the mandibulo-occipital assembly and the skull. (Fig. 24)

Logan (1962) believed there was pressure between the brace and skull and set about to measure this force, with the use of strain gauges and a potentiometer recorder. He was able to measure continuously any pressure exerted on the chin. It was found that the pressures varied from minute to minute according to the movements and posture of the patient. Also it varies within fairly narrow limits, except when the patient was changing his position or moving his head.

Pressures varied from zero to 10 lbs. However, the zero pressure did not occur frequently: about once in approximately 25 minutes, and then only for a few seconds. Logan concludes from these observations that an intermittent pressure of an average of 4 lb. is produced on the mandible by the Milwaukee Brace.

Schultz and Galante (1969), in measuring the force exerted by the Milwaukee Brace, using dynanometers, found that the spine was kept in traction with a total force of between 2.5 to 3 Kp. (Kiloponds). They claimed this force was approximately equally distributed between the mandible and occiput. A more comprehensive report of the above findings was recorded by Galante, et al

(1970), measuring the forces acting on the mandibular and occipital supports of the Milwaukee Brace in eleven patients. Measurable loads were present during all activities. In the standing position, the average total tractive force was 1.94 kilograms (4.3 lbs.) An increase in loads was noticed when the patients adopted a recumbent position; the average total traction was 3.08 kilograms when lying on the right side, and 5.06 kilograms in the supine position.

They further noticed that exercises increased all force components, as did deep breathing or coughing, where individual force components of up to 17 kilograms were recorded. Removal of the thoracic pad induced a significant increase in all patients. The highest loads were recorded in patients who ultimately required operative treatment for progression of the curve.

Cochran and Waugh (1969) measured the forced exerted by the Milwaukee Brace by the use of strain gauge load cells on ten Milwaukee Brace patients. When standing at ease with normal brace adjustment, total distraction was 5.7 lbs, (chin 3.3 lbs, occiput 2.4 lbs). Pressure on the right lateral pad 5.5 lbs and left lateral pad 4.8 lbs. These low values were thought to be in keeping with the dynamic concept of the brace. Routine measurements of corrective forces should reduce the subjective element in the application and evaluation of correction methods.

In Summary, the Milwaukee Brace:

(a) Does exert a force which greatly increases when the patient is supine, most likely due to the patient relaxing in the brace:

(b) The force exerted is intermittent, continuously changing with the position of the patient.

(c) The force exerted on the mandibulo-occipital structures is approximately 4 - 6 lbs.

11. METHODS OF MINIMIZING EFFECTS OF THE MILWAUKEE BRACE ON MAXILLO-FACIAL STRUCTURES

(i) Modification of the Brace.

Moe (1971) explains how the Milwaukee Brace in the period of 1950-1962 was aimed at gaining correction in conjunction with surgical fusion, or holding some degree of correction while awaiting later fusion. As the children reached skeletal maturity, the brace was gradually discarded and it became evident the correction obtained was permanent with little or no loss occurring thereafter. Urbaniak and Stelling (1969) reporting on the progression of Scoliosis, noted that completion of the excursion of the iliac crest epiphysis is generally considered to coincide with cessation of progression of the scoliotic deformity.

During the next 10 years, the brace was redesigned to greater efficiency, comfort and better cosmesis. The pelvic girdle became form-fitting with a new plastic material called orthoplast and with uprights being more closely contoured. The chin pad is replaced with a throat mould and a smaller contoured occipital pad (Fig. 33, 34, 35). Moe maintains, the replacement throat mould would act as a means of holding the head erect. Further in the use of the old type brace, the occipital pad tends to be placed too high, resulting in a forward thrust of the head, which adds to the forcible distraction against the chin support.

Keim (1971), in his review of the new type of Milwaukee Brace; maintained the throat mould does not distract the head, but gently keeps the occiput centred over the occipital pad. Both authors, Moe and Keim claim the new throat mould causes no dental or facial deformities, the reason being, they believed that the throat mould does not cause any pressure. However, they give no evidence that this mould reduces or eliminates the dental or facial deformities that occur. Eastham (1971) explains that the throat mould is under

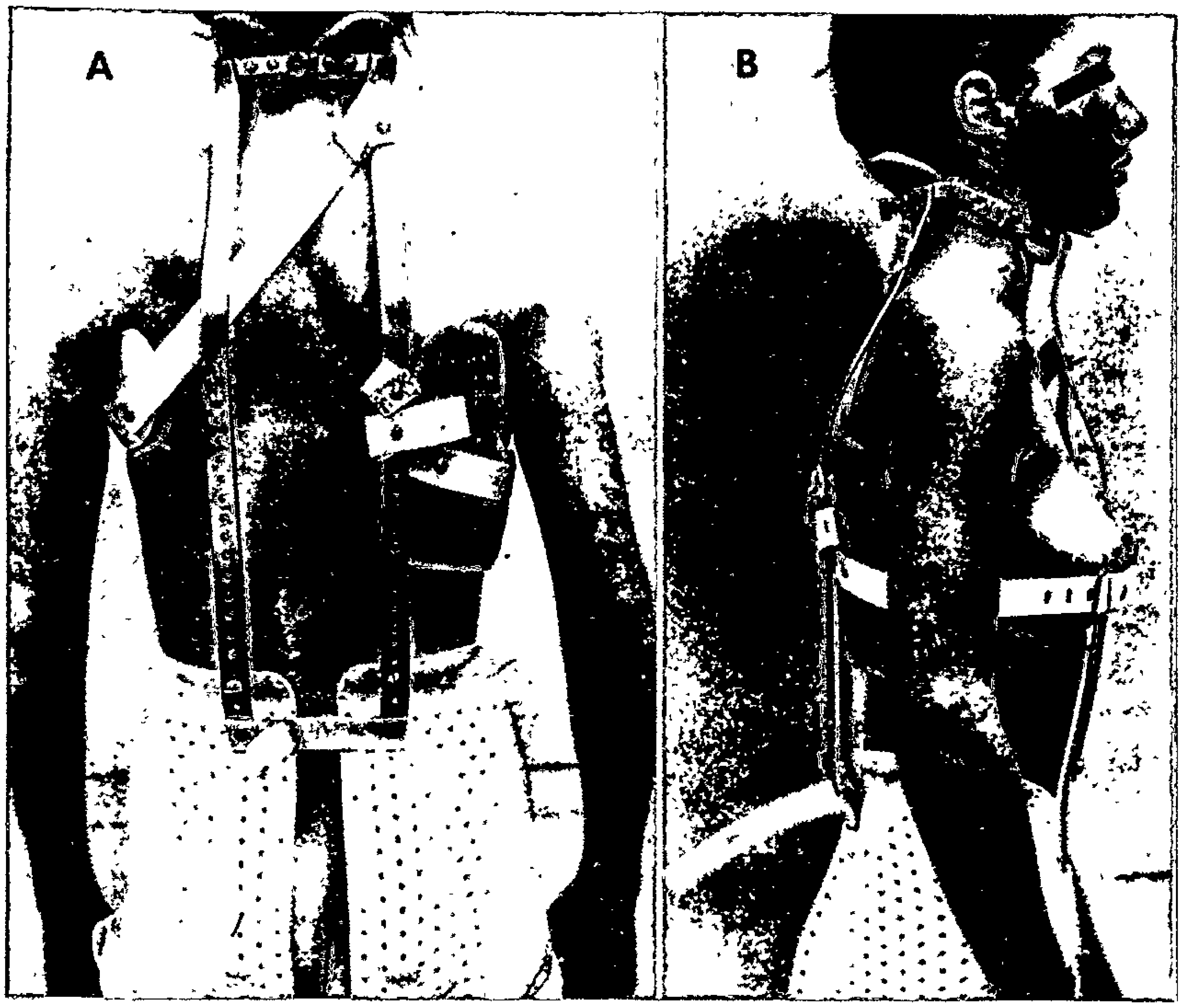


Fig. 33

The new Milwaukee Brace with (from Moe 1971, P.20)

(a) Throat mould.
(b) Smaller contoured occipital pads.
(c) Pelvic girdle moulded out of Orthoplast.
(d) Closer contoured vertical bars.
Compare this brace with that in figs.13, 14, 15, on P.32.

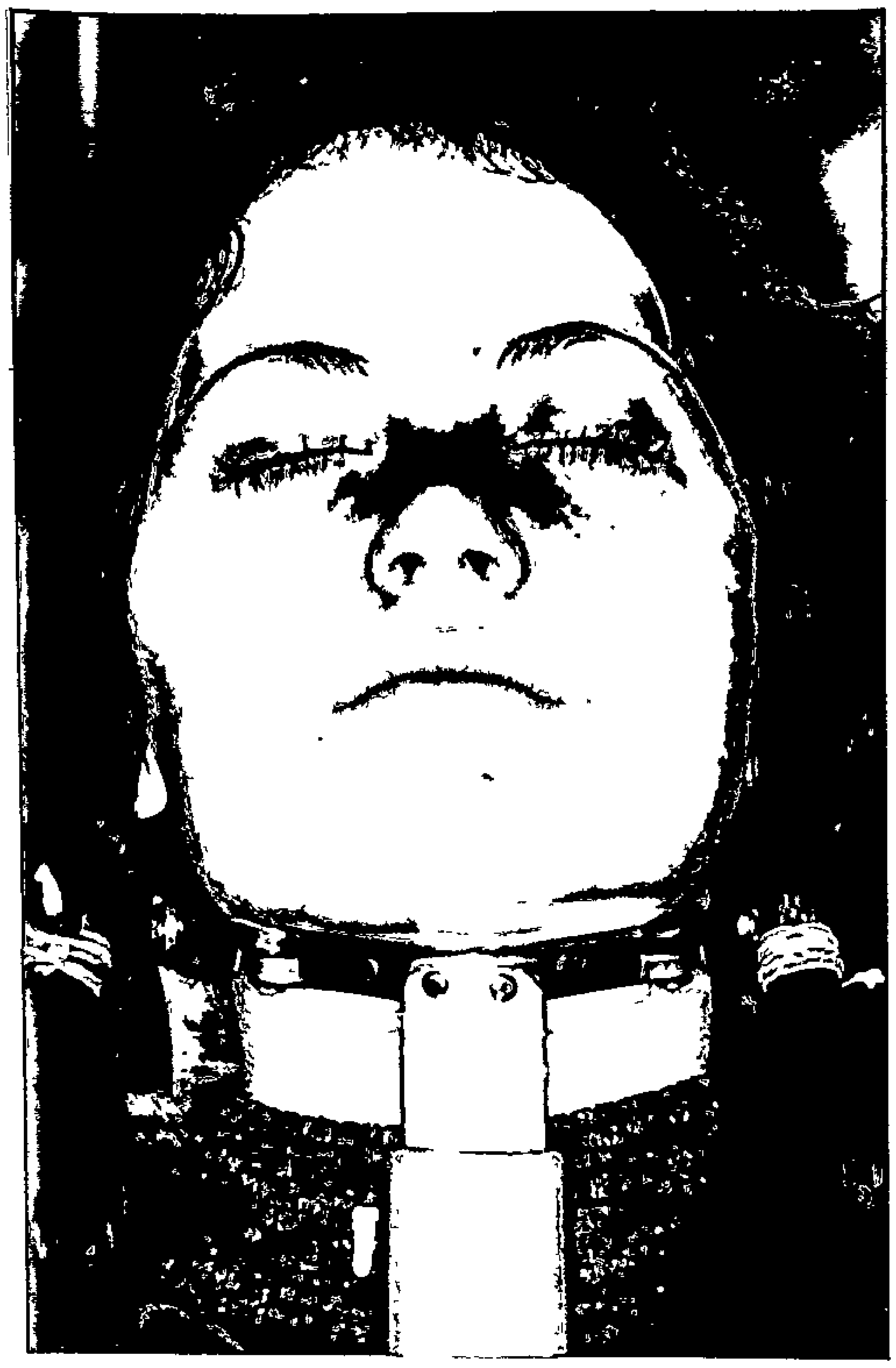


Fig. 34

Fig. 35

The throat mould which replaces the unaesthetic mandibular bar of the old style Milwaukee Brace. It is made of hard plastic.

evaluation, and that it is too soon at this stage to judge its usefulness. It should make orthopaedic surgeons and orthodontists wary that the new throat mould is not going to cause any orofacial deformities.

(ii) Stabilising Intraoral Appliances

Howard (1926) used intraoral splints to maintain the relative position of teeth during the stretching process of plaster jackets. He explained that this or any other intraoral appliance will neither prevent depression of the teeth, nor shortening of the lower one third of the face. With the twelve anterior teeth as added resistance and creating a unit of all teeth of each arch, it would follow that the shortening of the lower face would be materially decreased and the deflection of the maxillary incisors and canines would be definitely checked.

In the past ten years, after numerous reports of severe malocclusion and facial deformities, orthodontists were confronted with the question of what was the best design and best material for an orthodontic splint, to be used in conjunction with the Milwaukee Brace.

Bunch (1961), reporting on the use of a rubber dental positioner on 35 of 40 Milwaukee Brace cases after 3 and 1/2 years showed the dental occlusion remained stable and in some cases had improved. Any orthodontic failure in these Milwaukee Brace patients was put down to lack of patient co-operation in wearing the intraoral appliance.

Bunch stressed that it was possible to carry out minor tooth movements, and the importance of placing the positioner before the Milwaukee Brace was fitted. Recording that patients who did wear a positioner showed better comfort in their plaster cast or brace.

Some important conclusions from this study were:

(a) Rubber dental positioners appear to play a valuable correlative role in orthopaedic treatment of Scoliosis.

(b) Stability of orthopaedic braces or casts is enhanced.

(c) Dental positioners were well tolerated.

Further work using this type of intraoral appliance was carried out by Alexander (1966). In his experimental group of Scoliotics, a bulky co-polymer vinyl thermoplastic appliance was constructed. (Fig. 36) Recording the experiences of the patients, they began to get sore teeth 4-5 hours after the Milwaukee Brace was applied and the mouth piece inserted. For the next 48 hours, the gingiva and tongue were hypersensitive. By the end of three days, there was no complaint about the appliance. Patients were to wear the appliance at all times, except for eating or brushing the teeth. He found that patients who wore the mouth piece were more comfortable in their Milwaukee Brace than the control group.

Several problems arose with the appliance. One patient complained it was more difficult to wear the mouth-piece than the Milwaukee Brace. There were complaints of sore teeth, and the appliance changed colour, was difficult to clean, and became odorous. In two patients, the material failed after 4 months; believed to be due to nocturnal bruxism. Alexander, from his work, summarised the following points:

(a) The thermoplastic copolymer vinyl mouth-piece prevents extrusion of anterior teeth and appears to enhance the efficiency of the Milwaukee Brace. The mouth piece can be worn at all times except in eating and when cleaning.

(b) The mouth-piece does not prevent collapse of the lower face height or depression of molars.

(c) By taking advantage of the forces involved, it is possible to accomplish minor tooth movements.

Later, Eastham (1971) reports that, in Farleigh's follow-up of Alexander's work, the following observations were made. After 525 days, these appliance cases showed extreme collapse of facial height and a large increase in incisor proclination. It was concluded from this study that this type of appliance had

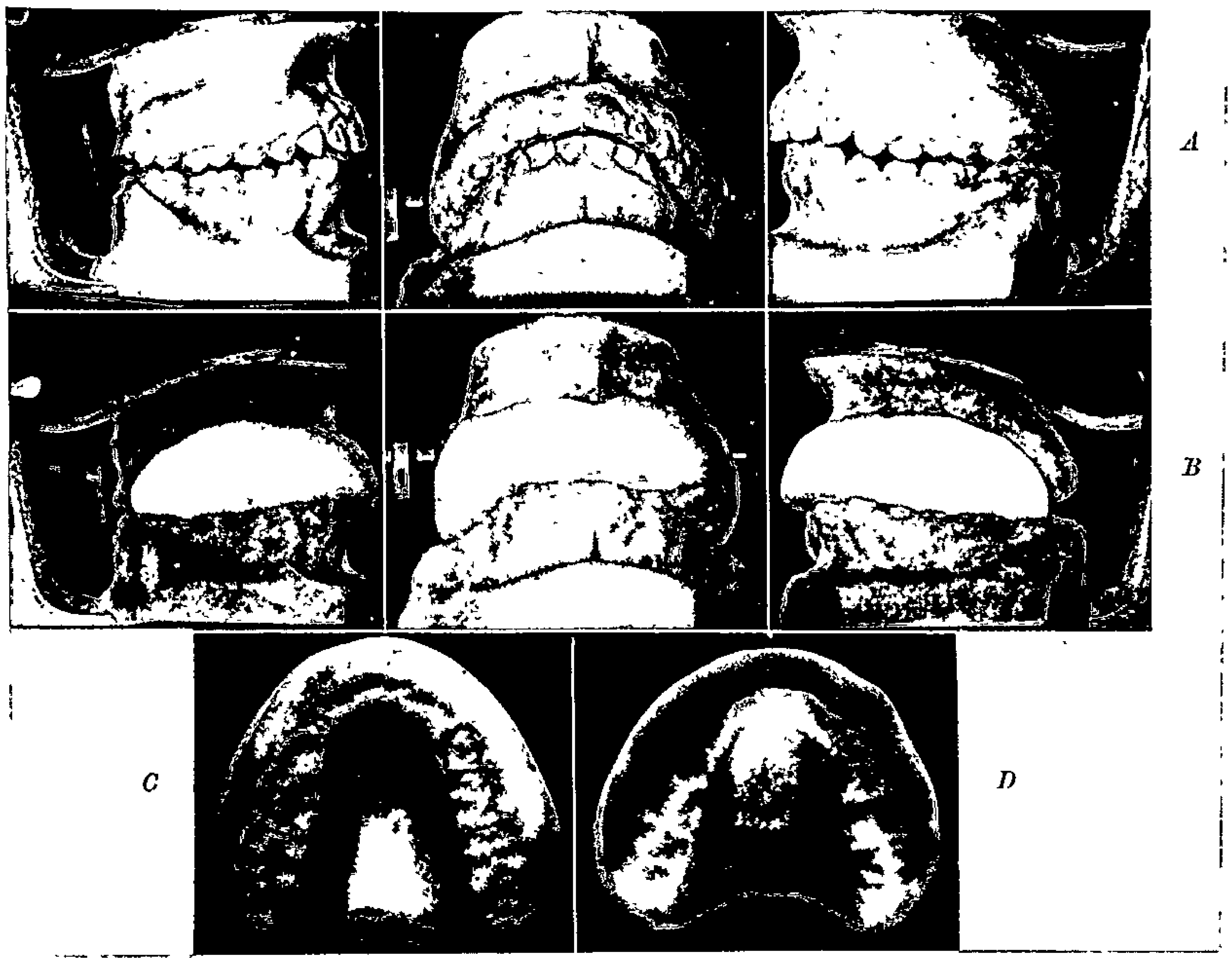


Fig. 36

The thermoplastic mouthpiece by Alexander and similar to the one used by Bunch (1961) (From Alexander 1966, p. 67)

- *(a) Shows the amount of freeway space used on articulated models.*
- *(b) Finished appliance on articulated models.*
- *(c) Appliance showing occlusion indentations from the lower arch.*
- *(d) Tissue fitting surface of the appliance.*

limited long term value as a stabilising appliance in Milwaukee Brace patients.

Thørs (1964), reporting on the use of acrylic splints as a prophylactic aid in Milwaukee Brace patients, noted that changes in the occlusion and cuspal interdigitation, induced by the pressure exerted by the chin pad, were considerably restricted. This appliance was found to be particularly suitable in cases where there were missing teeth, or malocclusion, before brace treatment began. If it is used consistently in conjunction with the chin pad of the brace, the splint will stabilise the sagittal and transverse relations of the dental arches.

Important questions which arise from Bunch and Alexander's work are:

(a) Should you expect a patient in an awkward, uncomfortable body brace 23 hours out of 24 hours, to put up with a bulky mass of thermoplastic vinyl in his mouth all day?

(b) Does the use of an orthodontic positioner enhance the efficiency of the Milwaukee Brace as claimed, considering no correlation could be established between spinal curvature correction and wearing the mouth piece in Milwaukee Brace therapy?

(c) What were the criteria for selection of thermoplastic material in the first place? (Thørs had found acrylic quite successful.)

Further work was carried out by Luedtke (1970), using a modified Vanguard Thermoplastic appliance. It was designed to fit over the maxillary teeth and palate with a palatal bar and interproximal lugs buried in the thermoplastic material. It was also designed to include half of the clinical crowns of all mandibular teeth. The appliance was issued prior to the final fitting of the Milwaukee Brace. The patients were instructed to wear the appliance 10-14 hours per day, leaving the oral cavity free during eating and the daytime.

Taking cephalograms of patients every 6 months, Leudtke recorded the following:

(a) Total face height may increase or decrease,

(b) Alveolar height decreased in every case except two,

(c) Jaw-to-jaw height decreased in all cases except one,

(d) The length of the body of the mandible increased in all patients undergoing active treatment.

(e) The interincisal angle decreased in all but 3 cases.

(f) Dental arch width, palatal-vault height, and horizontal and vertical overlap remained stable under the influence of the modified Vanguard appliance when used 14 hours per day.

Luedtke concludes that the modified Vanguard appliance seems to be the best available method known for maintaining intraoral architecture. This is surprising, considering his study examined only one appliance (Thermoplastic modified Vanguard) using one design.

In 1967, Lindskog published his results which included an evaluation of various types of orthodontic appliances which stabilise the dentition in Milwaukee Brace patients. The four appliances tested included :

(a) Thermoplastic Vinyl appliance

(b) Acrylic appliance

(c) Ticonium appliance

(d) Stainless Steel Bands

By using metal implants in the mandible and maxilla, and by superimposing serial cephalometric radiographs, evaluation of bony and dental changes was possible.

For the period of observation it was noted the appliances demonstrated varying degrees of success. All appliances tend to stabilise the teeth to varying degrees in transverse and sagittal direction, but the inability to control vertical displacement by some of the appliances was disappointing. There appeared to be no difference in the anterior facial height loss between the termoplastic bonded and control groups. The acrylic and ticonium appliances revealed slight intrusion of the teeth and very little reduction in the anterior facial height. Lindskog explains that although the temporary success in maintaining tooth stability is encouraging, it does not solve the problem of growth alteration. He concludes that there is definitely a reduction of facial growth in both mandible and maxilla.

Also using stainless steel bands, Pollack (1971) found the Milwaukee Brace patient still had severe deepening of the bite. He found most successful in containing the occlusion, a combination of the modified positioner and Hawley appliance.

Duyzings (1970) maintained it is important to support all the forces on the facial skeleton generated by the Milwaukee Brace, the distribution of pressure being critical. He believed that the teeth can be retained by a removable orthodontic appliance such as an oral screen, gum shield, or tooth positioner, which may be active or passive. It is difficult to see how the oral screen would stop deepening of the bite and flaring of the molars and premolars. It may reduce anterior flaring, but its use as an appliance to make the mandible a more stable pressure point is doubtful.

Combination of appliances were tried by Wiesjohn (1970) in the form of upper and lower Hawley retainers, claiming reduced dental deformity occurred in Milwaukee Brace patients who wore these appliances.

Freunthaller (1969) found the parallel use of activator with the Milwaukee Brace was not encouraging, believing there was lack of lateral support in the molar-premolar area. Favourable results using Knirscher splints made of transparent acrylic were achieved.

By this stage, numerous appliances had been tried with only the opinion of the author in most cases, as evidence of sucess or failure.

Eastham (1971) published the most comprehensive work to date on the value of various types of appliances that could be used.

In his study on the effectiveness of various appliances the following types were tested:

(A) Thermoplastic vinyl appliance similar in design to that used by Bunch;

(B) Impak Plastic and;

(C) Silastic appliances, which consisted of palatal coverage reinforced with mesh, and extended into the upper and lower labial sulcus;

(D) Processed acrylic appliance similar in design to the silastic postioner; that is, labial coverage extending to the height of anterior and posterior teeth;

(E) Vitallium splints, in the upper and lower arches, enabling the patient to close into their centric occlusion without interference from the splinting material. The appliances were to be worn during sleep.

(A) <u>THERMOPLASTIC VINYL:</u>

This material was cheap and easy to handle and it was thought it would be good for mixed dentition cases. However, it did not retain its resiliency or form and, as has been noted, it is of little use in long-term procedures. (Fig. 37)

(B) <u>IMPAK PLASTIC:</u>

This was a thermoplastic material, but more stable than vinyl at room temperature. It had a major problem in that it was porous, which meant that it discoloured quickly and developed an odour through bacterial contamination. It was studied only for a short period. (Fig. 37)

(C) <u>SILASTIC APPLIANCE:</u>

This appliance had a good resiliency and stability. It was possible to place such an appliance on severe malocclusion. It was also effective as a minor tooth-moving appliance. Retention of the appliance at night was a problem, possibly associated with difficulty in breathing. A disadvantage was the difficulty in trimming this material. (Fig. 38)

(D) PROCESSED ACRYLIC APPLIANCE:

The most significant finding was that the more rigid processed acrylic appliance had the least overall facial changes. Statistical significant decrease in many undesirable changes were recorded on serial cephalograms. This appliance was successful in stabilizing the dental occlusion. Very little loss in vertical dimension was recorded. Unlike Thørs, however, Eastham believed this to be due to the palatal coverage used. This palatal coverage was missing in Thørs' appliance. (Fig. 39)

(E) VITALLIUM SPLINT:

This splint provided good stability of the dental occlusion. As with the acrylic appliance, unless it was worn 8 hours per day, dicomfort occurred upon re-insertion. It was thought this appliance would be limited to the permanent dentition, mainly due to design. Also the high cost of manufacture was a disadvantage. (Fig. 40)

Fig. 37

1. *The thermoplastic vinyl splint covers the palate and the buccal surface of the teeth and extends into the vestibule. A bite index was established on the interior surface of the appliance for the lower teeth to rest in centric relation.*

2. *The Impak plastic splint has palatal coverage and extends over the maxillary teeth into the upper vestibule area. The incisal and occlusal surfaces of the lower teeth occlude into the inferior surface of the appliance.* (From Eastham 1971, P.448)

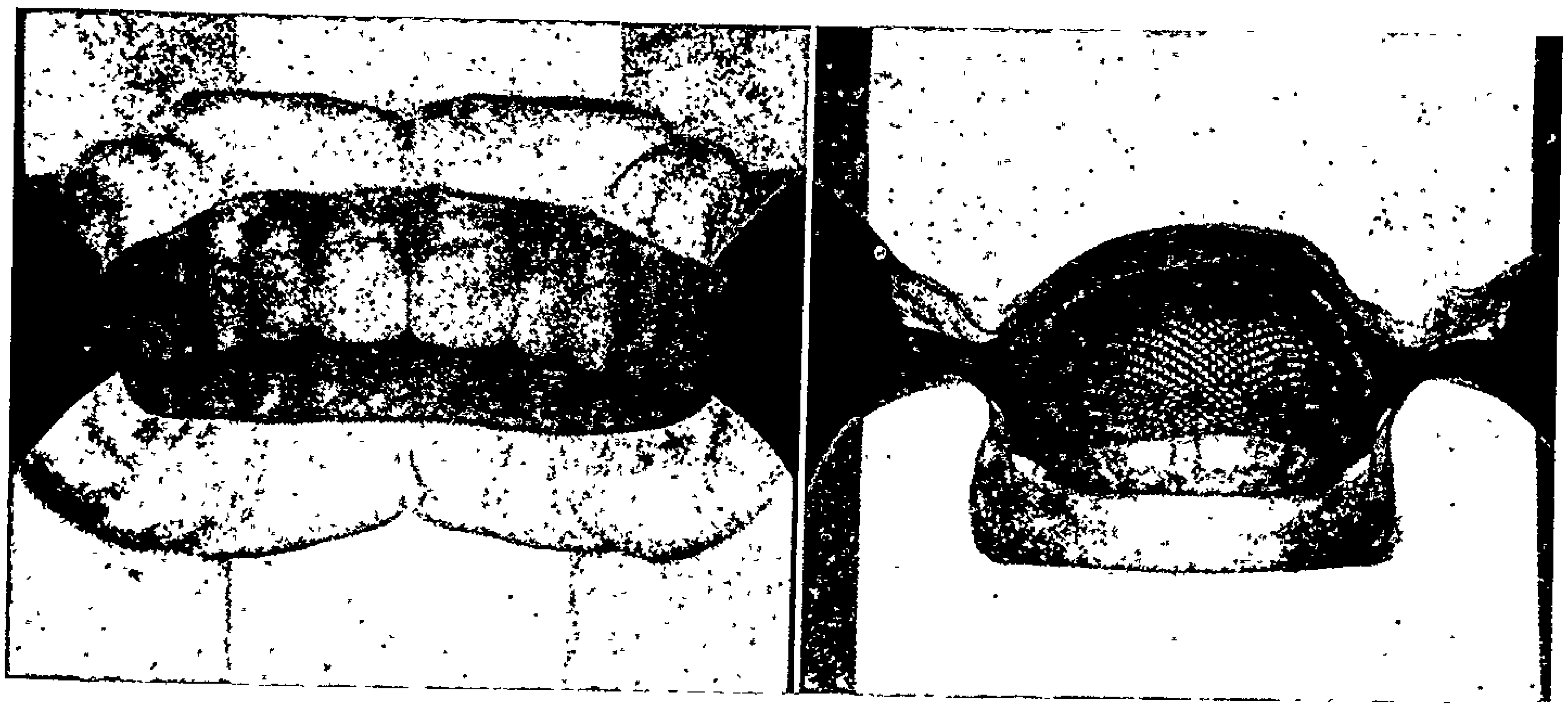


Fig. 38

The Silastic positioner. Hard silastic is used for stabilization and minor tooth movement. Wire reinforcement of the palate is used.
(From Eastham 1971, P449)

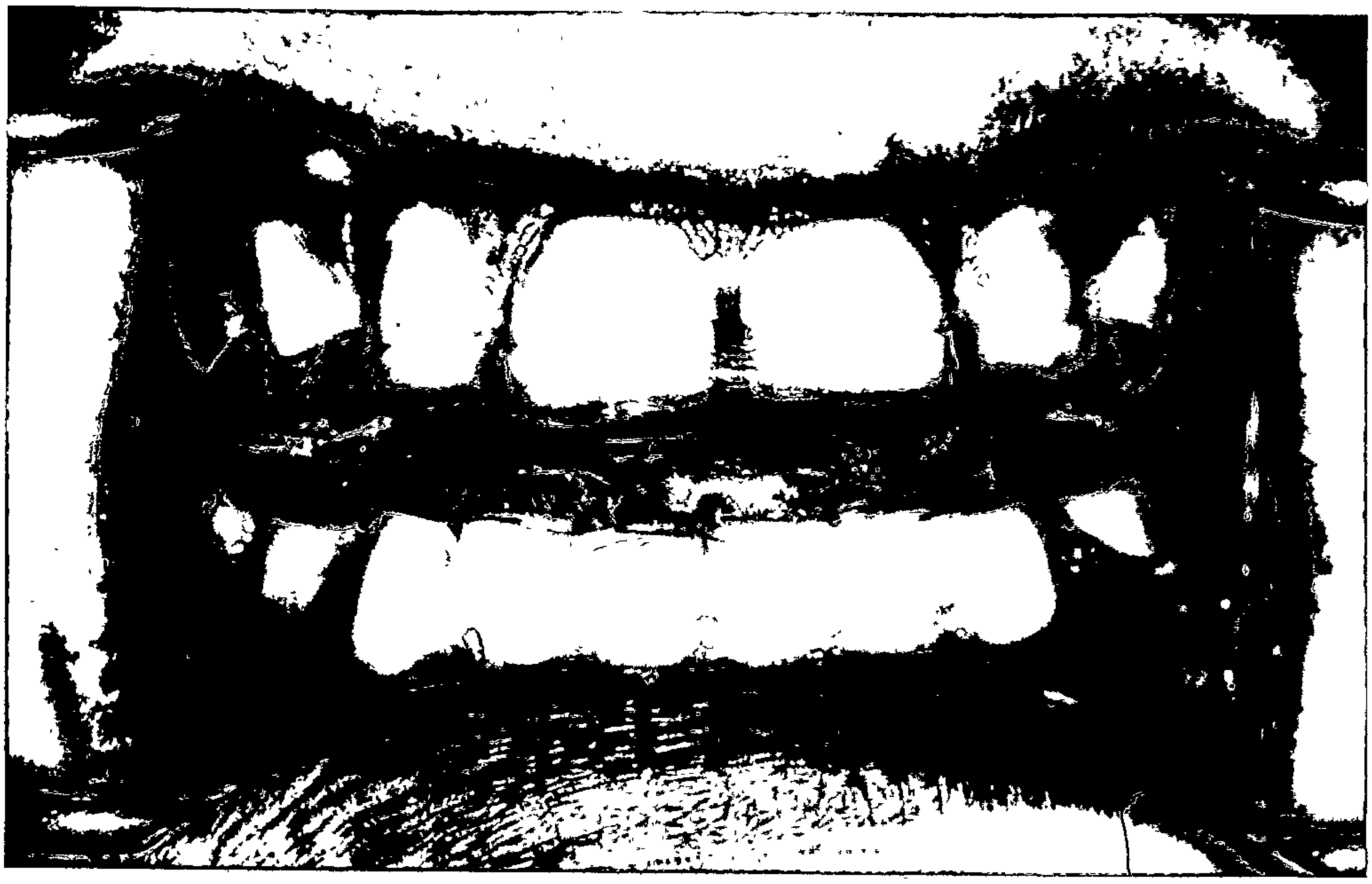


Fig. 39

The processed acrylic splint. The acrylic extends onto the labial surfaces of the maxillary teeth, the palate, and the incisal and occlusal surfaces of the lower teeth are registered on the inferior surface of the appliance.

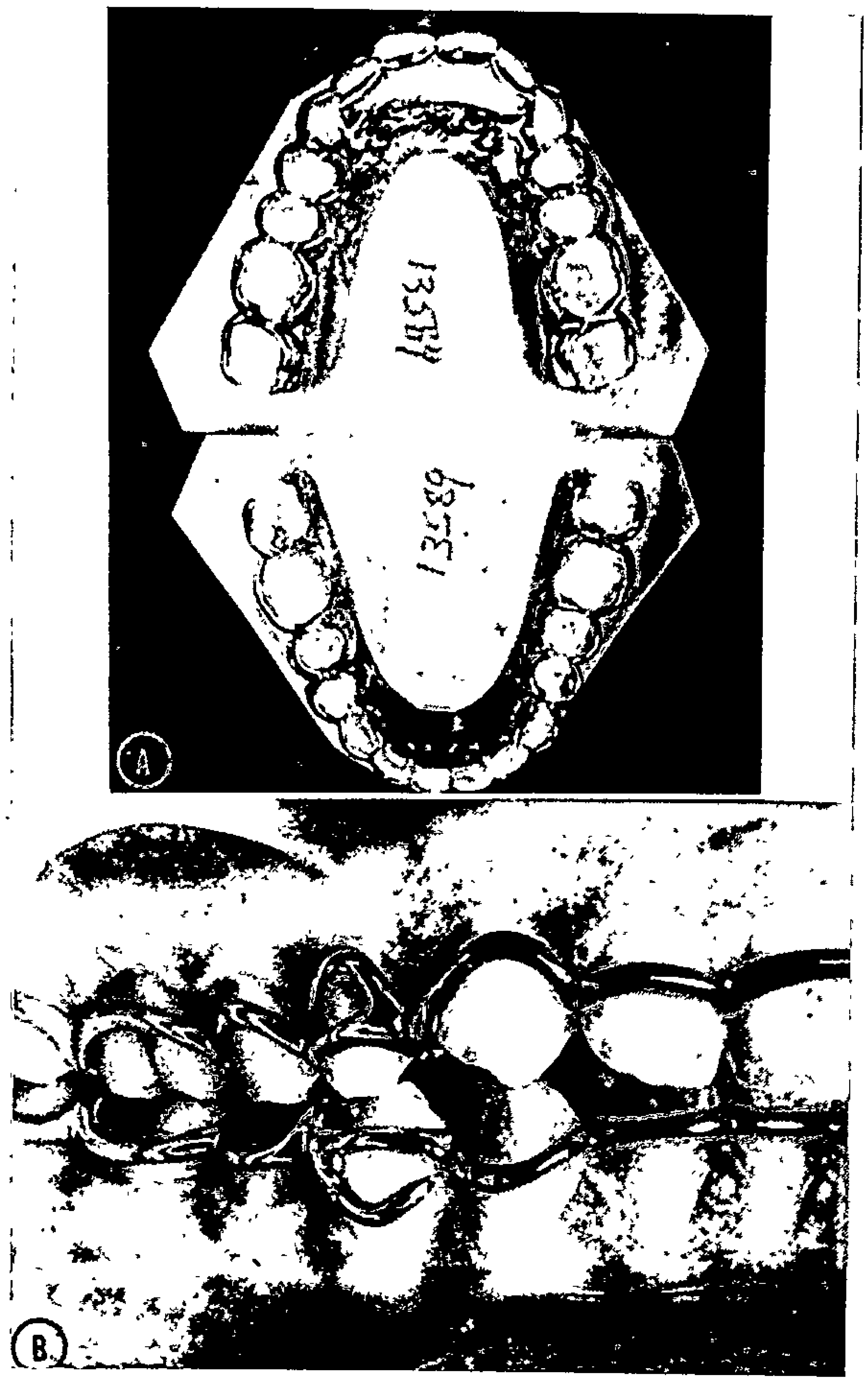


Fig. 40

The cast Vitallium Labio-lingual splints.

A. Clearance for lower incisors is possible by modifying the anterior lingual section of the upper splint.

b. Shows the canine clasp arms for retention.

(From Eastham 1971, p. 450).

A sixth appliance was tried in the form of banding and heavy arch wires. Patients had difficulty keeping this clean, and loose teeth were a problem.

It appears that the orthodontic answer to reduce or stop dento-facial changes is to bind or lock the occlusion so that the mandable and maxilla become a single stable distraction unit.

The type of splint which appears best suited is the processed acrylic with some palatal coverage.

However, the evidence also suggests, though the thermoplastic vinyl has limited use, it does have its place, as Hitchcock (1969) shows when he treated a Class 11 malocclusion with this type of positioner, whilst the patient was under Milwaukee Brace therapy.

Orthodontic treatment during and after Milwaukee Brace therapy by Logan (1967) shows that anterior retrusion and alignment can occur as the posterior segments of the dental arch are stabilised. Logan used a functional regulator designed by Dr. Fraenkel which consisted of posterior acrylic buccal sheilds connected anteriorly by labial arch wires.

12. EFFECT OF PRESSURE/TENSION ON BONE AS IT RELATES TO FACIAL GROWTH

Modification of man's skeleton has been carried out for centuries by various ethnic groups. The South Americans, (Glass (1961) shows, bound the skulls of their newborn by encasing the occipital and frontal regions between two wedge shaped pieces of wood. The Arawe tribe of New Britain produce cranial deformities, by binding the head of a newborn child in a tight bandage (Fig. 41) Perez-Martinez (1960). The Chinese women bind their feet. This makes the feet small and redirects growth in this area to make them taller. Note that all these deformities are permanent, the disfigurement produced is evidenced in their skeletal pattern at death.

The severe facial deformities and gross malocclusions caused by the Milwaukee Brace in many patients has been recorded. These deformities have little permanency about them. In fact, the patients' profile and malocclusion tends to return to its original state after brace removal. Moss (1961) would possibly explain this by the Functional Matrix Theory, assuming the muscles, nerves, vessels, connective tissue develop as normal, and that there is a redirection of bone growth and compression of bone in Milwaukee Brace patients. On removal of the brace the matrix would return the orofacial structures to normal, taking the maxilla and mandible with it. Moss (1964) claimed that it is the soft tissues and spaces which grow. These are then passively carried within their expanding matrices to new spatial relations. The growth observed, both at facial sutures and at cartilaginous areas, is all secondary.

On brace removal, the return to normal is the re-establishing of equilibrium between muscle and bone. A good example of this is shown by Foster (1965). He presents a case of a girl who developed poliomyelitis,

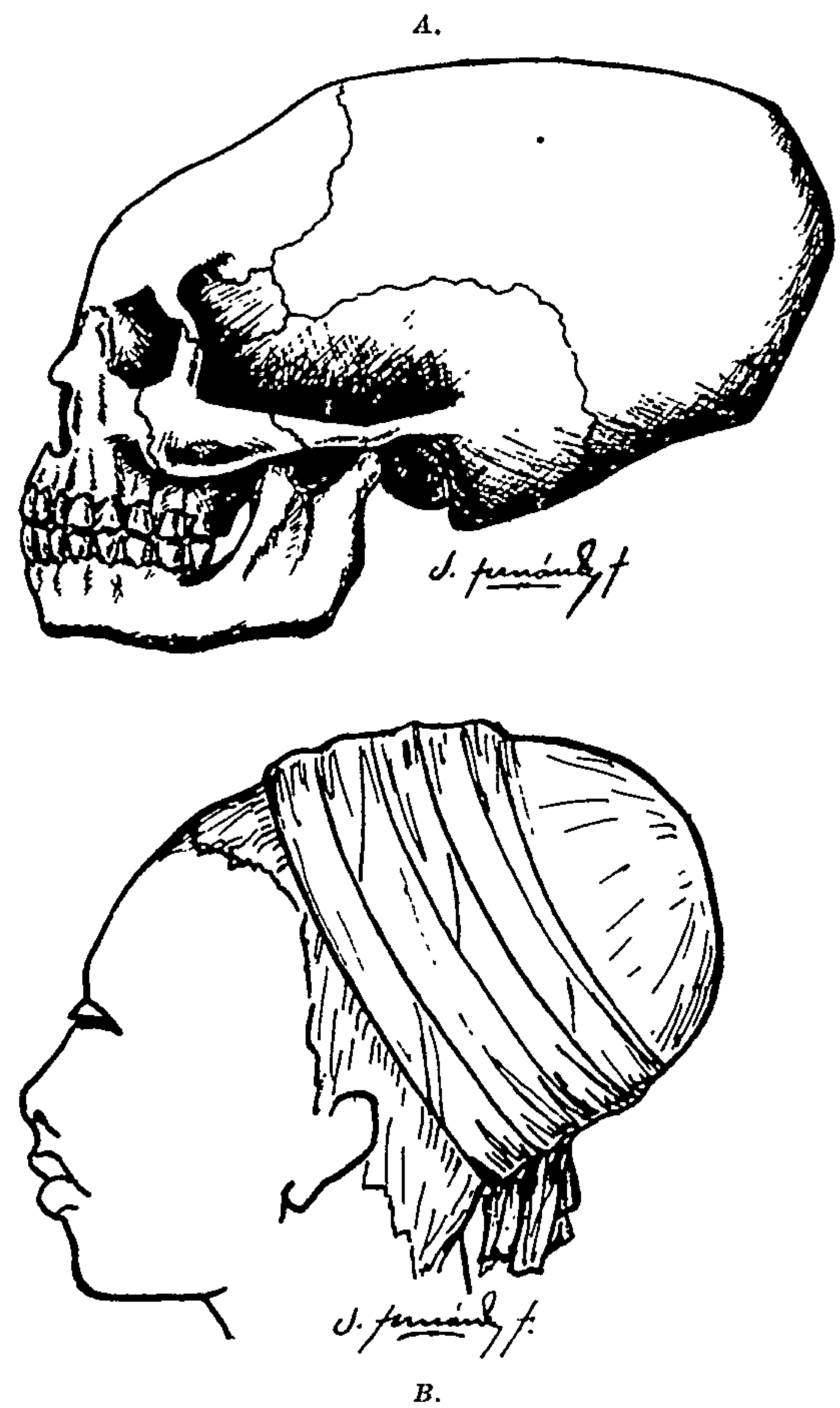


Fig. 41.

Annular deformities due to pressure on bone, common among Guanes Indians.

A. Effect on Skull.

B. Method of binding the head.

(From Carlos Perez-Martinez 1960 P. 541)

which affected the cervical muscles. The result was that the head collapsed, and was supported by the mandible which in turn was supported by the thorax. This total muscle collapse lead to excessive pressure on the mandible, from the head, which lead to a gross malocclusion. When the cervical spine was made rigid by fusion, the head was held erect and the occlusion and facial profile gradually returned to normal.

With the bound cranium in the Arawe tribe, there is only a small amount of muscle to influence the return of the head shape to normal; thus a greater chance of permanent bone deformation.

This return to normal of oro-facial structures may be related to the fact that the force exerted by the Milwaukee Brace though heavy, (4-5 lbs) is intermittent, thus allowing the bone and tissue time to repair. Whatever the reason, there is no obvious cause for the apparent return to their original state, other than functional influences.

As early as 1917, the mechanical aspects of bone had been established, Koch (1917), on the laws of bone architecture, states that the transformation of the inner structure of bone is altered with mathematical accuracy to conform to the new mechanical conditions. It is apparent then that pressure which leads to remodelling also leads to a new architecture in the deeper structure of the bone. It is also clear that pressure on bone will lead to resorption and apposition simultaneously. Gold (1967) believes the pressure which stimulates osteocytes starting the resorptive process, initiates a negative feed back mechanism that stimulates undifferentiated mesenchymal cells to change to osteoblasts to start compensative apposition of bone. He believed the initiating effect to be due to the pizeo electric phenomena of bone.
The pressure induced on the mandible by the Milwaukee Brace leads to resorption on the lower border and apposition at the ramus. Cutler, et al (1972) and Alexander (1966) state there is no actual destruction of bone by the

Milwaukee Brace, but rather a redirection of mandibular growth.

Janzen and Bluke (1965) carried out studies on continuous retracting force on the mandible in Malaca Mulattas and found that the mandibles of all experimental monkeys were lacking in vertical ramus height, indicating condylar growth did not reach its full potential. Lack of condylar growth brings about secondary changes in the total dento-facial complex.

They concluded that the use of the chin-cap in these cases resulted in lack of normal forward downward growth of the mandible in relation to the cranial base.

From normal mandibular growth studies (Bjork (1965), Brodie (1942), Odegaard (1970),) the areas which show mandibular growth redirection from Milwaukee Brace therapy are not surprising, if it is assumed that areas with greatest bone turnover during growth, will respond to pressure first. Brodie, with the use of Alzarin Red "S" dye, showed the most apparent growth site to be in the head of the condyle, others being the posterior border of the ramus, sigmoid notch and alveolar crest. These are areas that react to the Milwaukee Brace and show major changes.

Bjork, using metal implants, studied mandibular growth, He found the most pronounced remodelling occurred beneath the angular region. He noted that the direction of growth at the condyles in the sagittal plane varied widely with the average direction slightly forward in relation to the posterior tangent of the ramus. Also significant in Bjork's finding, is the difference between mean growth rates for juvenile and puberal periods. Characteristic of the juvenile period was fairly even growth of 3 mm., followed by a slight decrease to the pre-puberal minimum at 11 years 9 months. Then followed the puberal maximum of 5 mm. At puberty, where there is maximal growth, the alteration of facial pattern (due to restriction of mandibular pad of the Milwaukee Brace) would be expected to be greatest.

However, since the mandible continues to grow after menarche Tofani (1972), plus the fact the spurt of growth in stature occurs before the maximum increment in the mandible, the exact time that there is maximum restriction on facial growth may be difficult to determine.

In Milwaukee Brace patients, the main area of resorption is at the angle, and the lower border, with apposition on posterior border of the mandible. Also large turnover of bone occurs at the alveolus. (Lindskog 1967).

Hans (1948), studying the mechanical retardation of bone growth, found on placing a wire loop into the epiphysis of long bones, that the restraining power of the loop did not permanently destroy the proliferating properties of the columns of cartilage cells of the epiphyseal plate and bone growth was resumed after release of the hindering force. This could possibly simulate the mandibular pad of the Milwaukee Brace as restrictive on condylar growth, as recovery of growth occurs as soon as the pad is removed. Histologically, Cutler, et al (1972) have shown that hypertropic changes of fibroblasts to chondrocytes in the temporomandibular joints of monkeys who wore the Milwaukee Brace, were retarded, but not impeded.

Baume and Derichweiler (1961) obtained evidence that the condylar growth centre responds to functional therapy when an orthopaedic force is placed against the mandible. Upon treatment, the condylar head assumed a bilobed shape as part of a growth response that tended to compensate for induced mandibular displacement. Compensation, and/or redirection, appear to be key words that explain facial and mandibular growth alterations of Milwaukee Brace patients.

Korkhaus (1957) states that it is evident that among the factors which can lead to an increase or retardation of growth of the jaws, any which take part in the complicated process of the physiologic growth of the jaws can be responsible, such as the activities of the centres of growth, special hereditary tendencies of development, the endocrine glands, nutrition (especially the vitamins), deformation, pressures of the surrounding regions, and traumas. Storey (1972) records

> "All evidence to date points to the conclusions that the growth of bones is not immutable but can be changed by a variety of mechanical, hormonal, bacterial and genetic insults. Further, during development, sites of remodelling seem dictated by the requirement to maintain the bone form. The precise mechanisms of this are unknown but are probably related to the stresses and strains imposed by mechanical and chemical forces operating during growth and function."

Thørs (1964) believed that there was redirection and inhibition of growth in maxillo-facial structures of Milwaukee Brace patients, explaining that condylar growth ceased and compression of the sutures of the upper face leads to change in direction of those sutures.

One of the important histologic findings of Cutler, et al (1972) on their Milwaukee Brace monkeys was the initial growth response to the fronto-maxillary, fronto-zygomatic and zygomatico-maxillary sutures to the removal of the brace. There was rapid deposition of bone along the sutural margins perpendicular to the brace force. This is proof that redirection of sutural growth does occur.

However, this may be of little consequence in light of the studies by Scott (1956), who held that the maxilla is thrust downward and forward from the anterior segment of the cranial bone; but this process of bodily movement of the bone is not brought about by growth in the sutures, The separating force is provided by growth of the septal cartilage and the orbital contents.

Hinrichson (1968) showed that the degree of bone change induced by abnormal mechanical stress is determined not only by the direction of applied force, but also by the nature of growth sites affected. Stress on sutural growth has been well documented, Storey (1955). The question raised is what growth change is occurring in the upper face in the Milwaukee Brace patients. Does the redirection of sutural growth have the same apparent recovery as the mandible when the brace is removed, and is it in fact significant ?

Further orthodontic uses of these orthopaedic forces which redirect and/or inhibit growth of bone are put forward by Graber (1968). He believes these orthopaedic forces could be used to correct maxillo-mandibular anterio-posterior malrelations. However, when these forces are relaxed, what amount of "recovery" would occur to the previous antero-posterior maxilla-mandibular discrepancies?

On present evidence, one could possibly expect an orthopaedically corrected skeletal Class II or Class III discrepancy to return in part, to its original skeletal discrepancy. But the commonly occurring forward progression of the teeth would tend to be followed, in the process of "recovery" by a crowded dental state.

Due to the length of studies on growth alterations by orthopaedic forces, it may take years before it is apparent, the long term effects and consequences the Milwaukee Brace has on growth of facio-maxillary structures.

13. ORIGINAL WORK

AIM:

(a) To examine the effects of the Milwaukee Brace on the facio-maxillary structures, by cephalometric angular and linear measurements.

(b) To assess the orthodontic problem of Milwaukee Brace patients.

(i) MATERIAL

Medical and dental histories, lateral cephalograms, and study models of two groups of 29 patients were obtained.

A. EXPERIMENTAL GROUP. This group consisted of 29 Scoliosis and Kypho-scoliosis patients, who had worn the Milwaukee Brace for periods of between 3 months and 4 years. The age range was 5 years 9 months to 17 years 2 months.

These patients' records were taken from the Royal Prince Alfred Hospital Scoliosis Clinic, Sydney and from the Scoliosis Clinic at the Royal Alexandra Hospital for Children, Sydney. Three patients were referred from Orthopaedic Surgeons in Private Practice in Sydney.

B. CONTROL GROUP. This group consisted of a random selection of 29 pre-treatment orthodontic patients, taken from the University of Orthodontic Department, United Dental Hospital, Sydney. These patients were matched in age range and sex distribution with the experimental group. Apart from their malocclusions, these patients were normal healthy individuals.

(ii) METHODS

Medical Data.

A. EXPERIMENTAL GROUP. From the medical histories of the Scoliosis patients, the following information was collected:

(a) Patient's name, sex, and date of birth.

(b) Diagnosis and degree of spinal curvature.

(c) The period the Milwaukee Brace had been worn and its effectiveness, in degrees of spinal correction obtained.

(d) Associated abnormalities.

To give an indication of the effectiveness of the Milwaukee Brace, the amount of spinal curvature correction was recorded. (Blount, 1958 maintained, the aim of the Milwaukee Brace was to hold, and if possible, correct the spinal curvature). For simplification, its effectiveness was divided into three categories.

1. IMPROVING (I) - If the patients spinal curvature had decreased, the amount of correction in degrees was recorded.

2. HOLDING (H) - If the patients spinal curvature had remained stable, that is, it was approximately the same degree of curvature after Milwaukee Brace therapy as before.

3. WORSE (W) - If the patient's spinal curvature had increased, the amount of deterioration in degrees was recorded.

B. CONTROL GROUP The medical histories taken from patients on orthodontic consultation were used. These patients were normal healthy individuals except for their malocclusions. Their name, sex, and date of birth were recorded.

DENTAL DATA

Separate dental charts for all patients were specially constructed and the following information from lateral cephalograms, study models and dental histories recorded.

A. EXPERIMENTAL GROUP

(a) Dental Occlusion.

(b) Cephalometric skeletal pattern.

(c) Amount of anterior overbite (overlap of upper incisors over lower incisors) was expressed as a percentage.

(d) Crowding of anterior teeth.

(e) Spacing of anterior teeth.

B. CONTROL GROUP

(a) Dental malocclusion.

(b) Cephalometric skeletal pattern.

(c) Amount of anterior overbite (overlap of upper incisors over lower incisors) was expressed as a percentage.

(d) Crowding of anterior teeth.

(e) Spacing of anterior teeth.

The dental occlusions in both groups were recorded using Angle's Classification (1907) and a table constructed to compare the number and types of malocclusion for each group.

Both groups were then compared to a population sample. In this study the Tamworth Survey 1963 was used as a sample of 559 New South Wales schoolchildren aged, 4 - 17 years.

This survey is taken from unpublished material of Mr. K. Godfrey, Senior Lecturer, Department of Preventive Dentistry, University of Sydney.

CEPHALOMETRIC PROCEDURE

In measuring facial dimensions, 6 linear and 9 angular measurements were used. The cephalometric landmarks that make up the linear and angular measurements are defined by Krogman and Sassouni (1957). The 6 linear measurements are the same as those used by Alexander (1966). (Fig, 42).

Total anterior face height (1) - The distance, in millimetres from nasion to gnathion.

Upper anterior face height (2) - The distance, in millimetres from nasion along a line from nasion to gnathion to a point perpendicular to the anterior nasal spine.

Lower anterior face height (3) - The distance, in millimetres, from gnathion along a line from nasion to gnathion, to a point perpendicular to the anterior nasal spine.

Lower posterior face height (4) - The distance, in millimetres from articulare to gonion.

Upper molar height (5) - The distance, in millimetres, from the occlusal tip of the mesial cusp of the upper first molar perpendicular to the palatal plane.

Lower Molar height (6) - The distance, in millimetres, from the occlusal tip of the mesial cusp of the lower first molar perpendicular to the mandibular plane.

The 8 angular measurements are described by Downs (1948) and listed below: (Fig.43)

1. Stella-nasion to nasion subspinale (S.N.A.). This angle gives the anterior posterior relationship of the maxillary basal arch to the anterior cranial base.

2. Mandibular plane to Stella-nasion (M.P. to SN). This angle shows the relationship of the mandible to the cranium and gives an indication of vertical or horizontal growth of the mandible.

3. Stella-nasion to nasion pogonion (SN-Pog.) This angle gives the relationship of the anterior part of the mandible to the cranium and is known as the "facial angle".

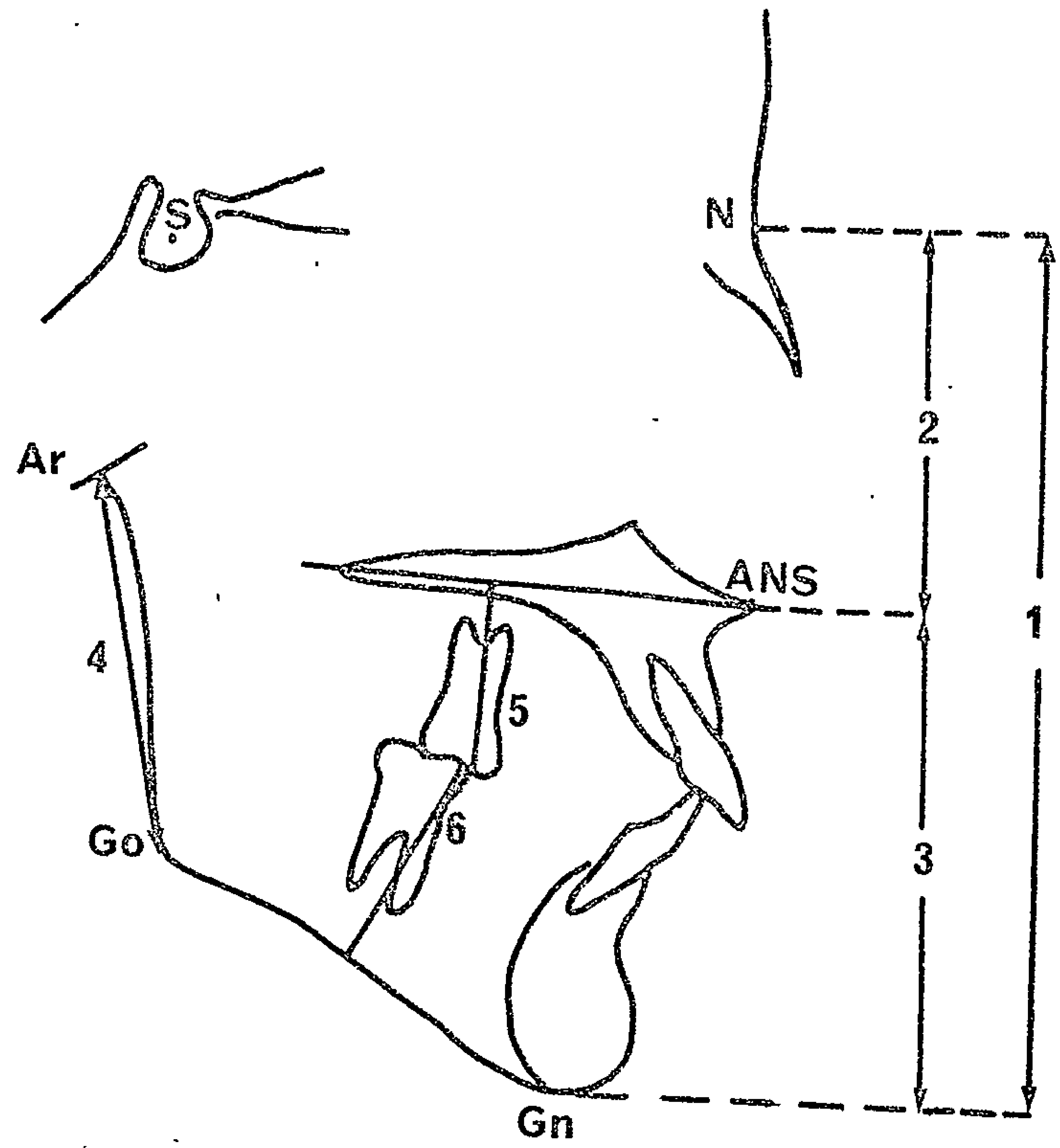


Fig. 42

Fig. 42 Cephalometric linear measurements used in this study.

4. Upper incisor to lower incisor (U.I. to L.I.). This angle measures the procumbency of the incisor teeth.

5. Lower incisor to mandibular plane angle (IMPA). This angle measures the procumbency of the mandibular incisors to the mandibular plane.

6. Upper incisor to stella-nasion (UI to S.N.). This angle determines the position of the maxillary central incisor to the anterior cranial base.

7. Gonial angle (Go.L): Formed when the mandibular plane intersects a line drawn from articulare to gonion.

8. Subspinale to nasion to supramentale (A-N-B). This angle gives an anterior posterior relationship of the mandible to the maxilla.

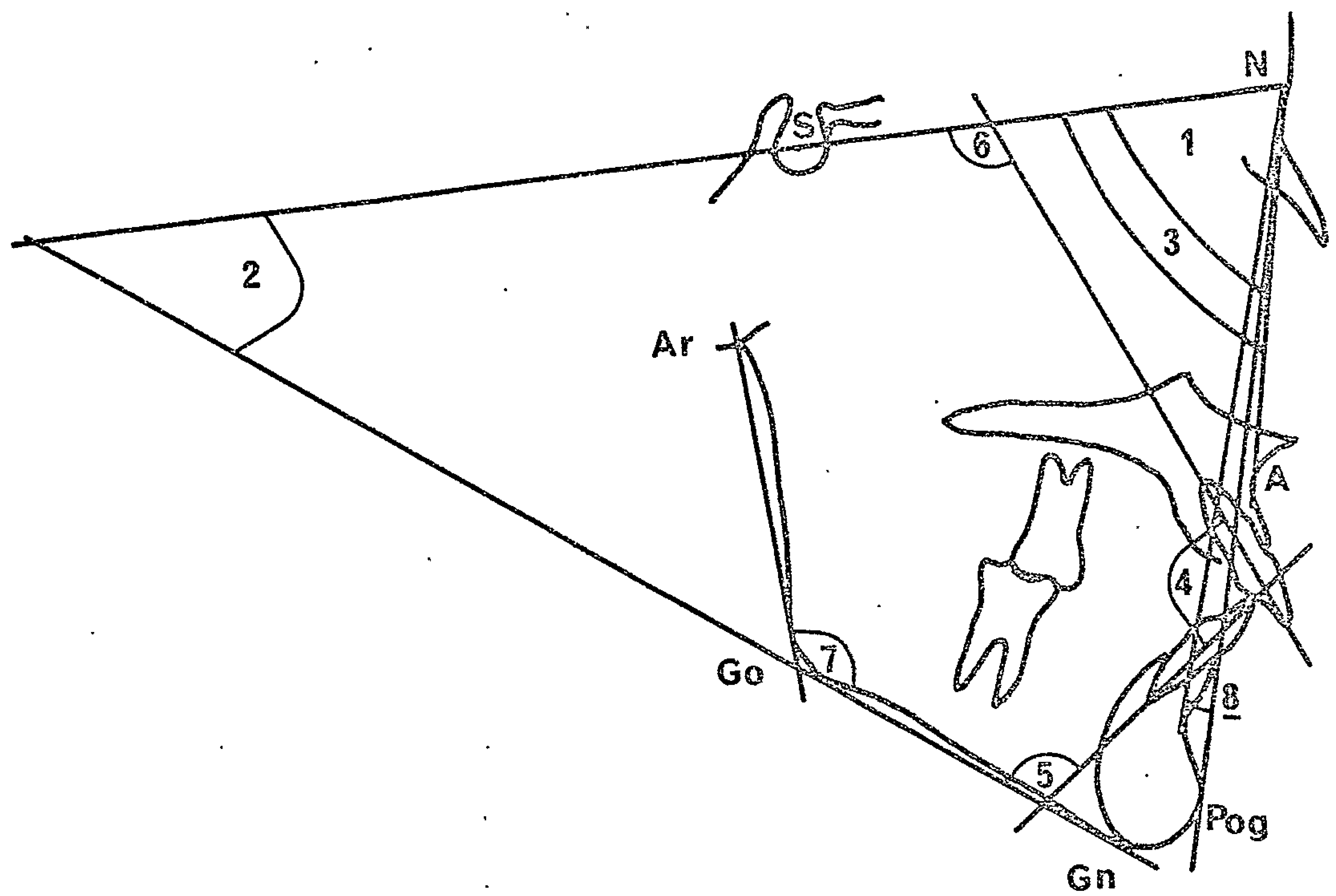


Fig. 43.

Fig. 43 Cephalometric anatomic land marks and angular measurements used in this study.

(iii) RESULTS

The results of this study are contained in Tables 11 to V1. The experimental and control groups consisted of 21 females and 8 males, each. Patients were grouped according to malocclusions, (ANGLE) Classification. Under the heading (PATIENT), patients initials were used and under the heading sex, the letters (F) for female and (M) for males were used.

Table 11, contains the medical data of the experimental (Scoliosis) group. The age range for this group was 5 years 9 months to 17 years 2 months with a mean age of 12 years. Out of a possible 28 patients, 8 patients showed an improvement of their spinal curvature, while wearing the milwaukee brace, 8 patients showed that their spinal curvature was holding, and 12 patients showed their spinal curvature had deteriorated. A total of 17 patients had medical abnormalities, 9 of these abnormalities were associated with Scoliosis.

Table 111, contains the dental data of the experimental (Scoliosis) group. Malocclusions (ANGLE) were evident in 28 out of 29 patients, or in 96.6% of cases. The type and number of malocclusions are recorded in Table V.

Skeletal patterns (Downs) revealed 20 patients with a skeletal 1 pattern, 6 patients with a skeletal 11 pattern and 3 patients with a skeletal 111 pattern.

The overbite was considered normal in 7 patients, deep in 9 patients, and very deep in 12 patients. There was 1 open bite, this patient being a thumb-sucker.

In this group, 13 patients showed no arch crowding of the lower anterior teeth, 12 patients had crowding of the lower anteriors, 1 patient had crowding of the upper anteriors, 3 patients showed crowding of the upper and lower anteriors.

Spacing of the upper anteriors was present in 14 patients, 1 patient had spacing of upper and lower anteriors, and 14 patients showed no anterior spacing.

Table 1V contains the dental data of the control (Pretreatment Orthodontic) group. The age range of this group was 6 years, 2 months, to 18 years 7 months, with a mean age of 11 years 8 months. All patients in this group had malocclusions (ANGLE). The skeletal pattern (Downs) revealed, 16 patients with a skeletal 1 pattern, 11 patients with a skeletal 11 pattern, 2 patients with a skeletal 111 pattern.

In this group, 16 patients had normal overbite, 5 had deep overbite, and 8 had very deep overbite.

Anterior crowding figures, showed 9 patients with no anterior crowding, 11 patients with upper and lower anterior crowding, and 4 patients with lower anterior crowding, 5 patients with upper anterior crowding.

No spacing was evident in 22 patients in this group, and 7 patients showed spacing in the upper anterior teeth.

Table V shows a comparison of incidence and types of malocclusions (ANGLE), between the experimental, control group and the Tamworth Survey.

Table V1, contains the cephalometric data of the control and experimental groups. A comparison between groups by the "t" test was carried out.

Tables of all individual cepholometric angular and linear measurements used in this study are recorded in Appendix B. (Table VII and VIII)

TABLE II MEDICAL DATA OF THE SCOLIOSIS GROUP

PATIENT	AGE (yrs/mths)	SEX	TYPE OF SCOLIOSIS	PERIOD IN BRACE (yrs/mths)	EFFECT OF BRACE * (in degrees)		ASSOCIATED ABNORMALITIES
MM	13/10	F	Thoracic	–/10	I	5	Nil
JT	13/6	F	Double Primary	–/3	I	12	Skin Lesion
VH	12/–	M	Thoraco-lumbar	4/–	W	13	Polio
SL	9/2	F	Thoraco-lumbar	3/–	I	12	Deaf, brain damage
JS	12/4	F	Thoraco-lumbar	–/3	I	17	Nil
DW	16/–	M	Kypho-Scoliosis	–/6	H	0	Mentally backward
MK	13/4	F	Lumbar	–/6	I	5	Mentally backward
LS	9/–	F	Lumbar	12/2	H	–	Nil
DF	13/4	M	Kypho-Scoliosis	–/4	H	–	Nil
BP	9/7	F	Kypho-Scoliosis	1/6	I	23	Nil
KR	17/2	F	Kypho-Scoliosis	–/7	W	10	Neuro fibromatosis
SE	15/8	F	Thoraco-Lumbar	–/6	W	14	Cafe au lait spots
JM	17/2	F	Thoracic	1/–	I	4	Nil
CR	11/6	F	Thoraco-Lumbar	1/9	W	11	Nil
YF	15/11	F	Thoraco-Lumbar	–/5	H	–	Nil
JP	15/3	F	Thoraco-Lumbar	–/5	H	–	–
PR	8/11	M	Thoracic	3/4	H	–	Congenital limb deformities
PC	10/11	F	Thoraco-Lumbar	2/6	W	4	Facial Palsy
JM	10/6	F	Kypho-Scoliosis	1/6	W	–	Muscular dystrophy
MC	17/3	F	Thoraco-Lumbar	4/–	I	8	Muscular dystrophy
CT	12/8	M	Thoraco-Lumbar	1/5	H	–	Polio
JS	12/9	F	–	–	–	–	–
KS	6/5	M	Thoraco-Lumbar	–/9	W	3	Nil
KL	7/7	F	Lumbar	–/3	W	15	Nil
CB	13/1	F	Double Primary	4/–	W	24	Mentally backward, Polydactly
JM	7/2	M	Thoraco-Lumbar	2/6	H	–	Mentally backward, Brachiocephaly
BW	5/9	M	Thoracic	–/4	W	32	Marfans Syndrome
TM	9/11	F	Kypho-Scoliosis	1/6	W	5	Nil
RP	11/3	F	Thoraco-Lumbar	1/5	W	40	Neurofibromatosis

*(I) — Spinal curvature improving
(H) — Spinal curvature holding
(W) — Spinal curvature is worse

TABLE III DENTAL DATA OF THE SCOLIOSIS GROUP

PATIENT	DENTAL PATTERN (Angle)	SKELETAL PATTERN (Downs)	OVERBITE*	ANTERIOR CROWDING	SPACING
MM	Class II Div 2 malocclusion	Class I	Very deep	lower	upper anteriors
JT	Class II Div 2 malocclusion	Class II	Very deep	lower	No
VH	Class II Div 2 malocclusion	Class I	Very deep	No	No
SL	Class II Div 2 malocclusion	Class I	Deep	No	upper anteriors
JS	Class II Div 2 malocclusion	Class I	Deep	lower	upper anteriors
DW	Class II Div 2 malocclusion	Class I	Very deep	lower	No
MK	Class II Div 2 malocclusion	Class I	Deep	lower	upper anteriors
LS	Class II Div 2 malocclusion	Class II	Very deep	lower	No
DF	Class II Div 2 malocclusion	Class I	Deep	lower	upper anteriors
BP	Class II Div 2 malocclusion	Class I	Normal	No	upper anteriors
KR	Class II Div 2 malocclusion	Class II	Deep	No	upper anteriors
SE	Class II Div 1 malocclusion	Class I	Very deep	lower	upper anteriors
JM	Class II Div 1 malocclusion	Class I	Very deep	lower	upper anteriors
CR	Class II Div 1 malocclusion	Class I	Very deep	No	upper anteriors
YF	Class II Div 1 malocclusion	Class II	Very deep	lower	upper anteriors
JP	Class I malocclusion	Class III	Normal	upper & lower	No
PR	Class I malocclusion	Class II	Very deep	No	No
PC	Class I malocclusion	Class I	Normal	lower	upper anteriors
JM	Class I malocclusion	Class II	Very deep	No	No
MC	Class I malocclusion	Class I	Normal	No	Lower and upper anteriors
CT	Class I malocclusion	Class I	Deep	upper & lower	No
JS	Class I malocclusion	Class I	Very deep	upper & lower	upper anteriors
KS	Class I malocclusion	Class I	open bite	No	upper anteriros
KL	Class I malocclusion	Class I	Deep	No	No
CB	Class III malocclusion	Class I	Deep	upper	No
JM	Class III malocclusion	Class III	Normal	No	No
BW	Class III malocclusion	Class I	Normal	lower	No
TM	Class III malocclusion	Class III	Normal	No	No
RP	Class I occlusion	Class I	Deep	No	No

*The degree of overbite is measured as a percentage overlap of the upper over the lower insisor teeth.

0- 25% — Normal
25- 75% — Deep
75-100% — Very deep

TABLE IV DENTAL DATA OF THE PRETREATMENT ORTHODONTIC GROUP

PATIENT	AGE (yrs/mths)	SEX	MALOCCLUSION (Angle)	SKELETAL PATTERN (Downs)	OVERBITE*	ANTERIOR CROWDING	SPACING
KD	9/6	M	Class II Div I	Class I	Normal	No	No
MD	9/9	F	Class II Div I	Class II	Very Deep	No	No
GH	12/9	F	Class II Div I	Class I	Deep	Lower	No
MV	9/5	F	Class II Div I	Class II	Deep	Upper & Lower	No
JE	13/1	F	Class II Div I	Class II	Deep	Lower	No
RD	11/11	M	Class II Div I	Class II	Very Deep	No	Upper anteriors
PH	14/8	F	Class II Div I	Class I	Very Deep	Upper & Lower	No
RS	7/9	F	Class II Div 2	Class II	Very Deep	No	Upper anteriors
SN	15/3	F	Class II Div 2	Class I	Very Deep	Upper & Lower	No
NS	11/4	F	Class II Div 2	Class I	Normal	Upper & Lower	No
LF	18/7	F	Class II Div 2	Class II	Very Deep	Lower	No
DM	13/11	F	Class II Div 2	Class I	Deep	Upper	Upper anteriors
WB	9/11	M	Class II Div I	Class II	Normal	Upper	No
EG	9/3	F	Class II Div I	Class I	Deep	No	No
JP	14/7	M	Class I	Class I	Normal	No	Upper anterior
KN	10/7	F	Class I	Class I	Very Deep	Upper	No
DO	10/4	F	Class I	Class I	Very Deep	No	No
KP	7/3	F	Class I	Class I	Normal	Upper	Upper anteriors
SH	12/2	F	Class I	Class I	Normal	No	No
FP	11/4	F	Class I	Class II	Normal	Upper & Lower	No
EM	14/3	F	Class I Bimax.	Class II	Normal	Upper & Lower	No
DM	13/4	M	Class I	Class I	Normal	Upper & Lower	Upper anteriors
EF	12/2	F	Class I	Class I	Normal	Upper & Lower	No
CD	13/9	F	Class I	Class II	Normal	Lower	No
MP	13/1	M	Class I	Class II	Normal	Upper & Lower	No
RC	13/6	M	Class III	Class I	Normal	Upper	No
RD	12/5	F	Class III	Class III	Normal	Upper & Lower	No
RH	6/2	M	Class III	Class I	Normal	No	Upper anteriors
CA	6/10	F	Class III	Class III	Normal	Upper & Lower	No

*The degree of overbite is measured as a percentage overlap, of the upper over the lower incisor teeth.
(0- 25%) — Normal
(25- 75%) — Deep
(75-100%) — Very deep

TABLE V COMPARISON IN PERCENTAGES OF MALOCCLUSIONS BETWEEN EXPERIMENTAL GROUP, CONTROL GROUP, AND THE TAMWORTH SURVEY.

Malocclusion (Angle)	Experimental Group	Control Group	Tamworth Survey*
Class I	31.0	37.9	71.9
Class II			
Div. 1	13.8	31.0	11.8
Div. 2	37.9	17.2	5.6
Class III	13.8	13.8	2.2
Normal Occlusion	3.4	—	8.6

* Used as a representative sample of the population of New South Wales schoolchildren aged 4-17 years.

TABLE VI CEPHALOMETRIC STATISTICS

LINEAR AND ANGULAR MEASUREMENTS		EXPERIMENTAL GROUP			CONTROL GROUP				
		MEAN X	STANDARD DEVIATION	STANDARD ERROR	MEAN X	STANDARD DEVIATION	STANDARD ERROR	"t" VALUE	PROBABILITY
Total Anterior Face Height (T.A.F.H.)	(mm)	102.1	8.0	1.5	114.4	6.8	1.2	6.40	< 0.001
Upper Anterior Face Height (U.A.F.H.)	(mm)	45.6	4.9	0.9	50.2	3.8	0.7	4.00	< 0.001
Lower Anterior Face Height (L.A.F.H.)	(mm)	56.5	4.6	0.9	64.2	5.4	1.0	5.70	< 0.001
Posterior Face Height	(mm)	34.8	4.7	0.9	42.0	4.6	0.8	6.00	< 0.001
Lower Molar Height	(mm)	25.8	3.2	0.6	29.4	2.5	0.4	5.00	< 0.001
Upper Molar Height	(mm)	18.3	2.9	0.5	20.9	2.6	0.5	3.71	< 0.001
SNaPog	(degrees)	79.8	4.1	0.8	79.1	4.2	0.8	0.62	< 0.6
MP to Sn	(degrees)	31.5	5.3	0.9	34.9	6.3	1.2	2.26	< 0.05
U1 to L1	(degrees)	123.1	19.9	3.6	127.9	11.7	2.2	1.14	< 0.3
I.M.P.A.	(degrees	95.9	12.3	2.3	91.8	9.8	1.8	1.41	< 0.2
U1 to Sn	(degrees)	111.0	12.6	2.3	105.8	9.6	1.8	1.79	< 0.1
ANB	(degrees)	2.4	2.4	0.5	3.4	1.9	0.4	1.56	< 0.2
SNa	(degrees)	79.7	4.5	0.8	80.3	4.5	0.8	0.53	0.6
Gonial	(degrees)	125.2	5.4	1.0	130.1	6.8	1.2	3.14	< 0.01

(iv) DISCUSSION

Out of 28 Scoliosis patients, 12 showed an increase in their degree of spinal curvature during Milwaukee Brace therapy. Though it appears the Milwaukee Brace was effective in a little over 50% of cases, numerous variables have to be considered. These include the variables, (1-4) listed below, which also effect the results of this orthodontic study.

(1) Length of time the Milwaukee Brace is worn. - The longer the patient wears the brace, the greater the chance of spinal curvature correction, and adverse effects on the jaws and associated structures.

(2) Age of the patient. - The Milwaukee Brace would have its greatest effect during puberty, than at any other time. Also young bone is less resistant to pressure than older, more calcified bone.

(3) Type of Scoliosis. - Specific types of scoliosis increase their curvature more quickly than others.

(4) Management of Scoliosis. - Orthopaedic surgeons vary in their treatment procedures, in using the Milwaukee Brace, particularly in time of patient recall and height of adjustment of the brace.

(5) Initial occlusion. - It would be expected a full interdigitating occlusion to be more stable to a distraction pressure than a malocclusion.

It has been recorded previously that the idiopathic disease process that produced Scoliosis, is still present during Milwaukee Brace Therapy. This diseased state of the body could be related to alteration in facial growth and the development of malocclusion. (Alexander 1966). Or as Stilweel (1927), believed, there may be a correlation of malocclusion and Scoliosis to body posture.

CEPHALOMETRIC ANALYSIS

Statistically significant linear differences between the experimental and control groups were: Total anterior face height 12.3mm., lower anterior face height 7.7mm., upper anterior face height 4.6mm., posterior face height 7.2mm., lower molar depression of 3.6mm., upper molar depression 2.6mm. This decrease in face height with concomittant molar depression, is similar to the findings of Alexander (1966), Duyzings, (1969), Hodges (1965), Lindskog (1969) and Thørs (1969).

This study indicates the Milwaukee Brace does effect linear facial dimensions. The most significant finding is the difference in total anterior face height, which is made up of compression, mainly of the lower face 7.7mm., and secondly, the upper face height, 4.6mm.

The large difference in posterior face height between the groups, 7.2mm., indicates the complete lower border of the mandible, not just the anterior section, is under pressure.

The compression of facial structures in the scoliosis group, could be due in part to deepening of the bite. This group showed (72.6%) with deep and very deep bite, compared with (44.8%) in the control group.

The loss of anterior face height could be related to the fact that many Scoliosis patients are in the mixed dentition stage during Milwaukee Brace Therapy. These patients may have incisor and first molar contact only in their dentitions,and these teeth would take the pressure from the brace. On observation there may be a negative correlation between the number of teeth in occlusion (stability of occlusion) and the severity of malocclusion in Milwaukee Brace patients.

Noticed in the experimental group, in those patients with severe dental and facial alterations, was some difficulty in speech and functional head and jaw movements, when confined to the Milwaukee Brace. A common complaint reported by these patients, was the difficulty in performing their oral hygiene.

This difficulty in speech could in some way, be due to the tongue occupying a smaller space in the oral cavity. Also the tongue being a strong muscular organ, would aid in the proclination of the anterior teeth. (Figs.44,45).

It is felt the tongue played a major part in the gross dental alterations of patient M.C. (Figs. 25. 26 27). Apart from the teeth being proclined, spaced and no deepening of the bite, the first premolars were in buccal crossbite.

Though not generally statistically significant, the angular cephalometric analysis lends support to the finding that the lower facial structures are compressed and pushed upwards. The measurement, Mp to Sn difference, between the control and experimental group was 3.4 degrees (statistically significant, $p<0.05$) and the I.M.P.A. 3.8 degrees (not statistically significant (p.0.2) This indicates that the mandible has been pushed upwards and the lower incisors proclined in comparison to the control group; or, it could be redirection of growth of the mandible in a more horizontal plane.

The angles SNA, SNPog, U1 to L1, and ANB were similar in both groups, though tending to be larger in the control group, which consisted of a group of patients with malocclusion and frequent jaw discrepancies.

The gonial angle shows a mean difference of 4.9 degrees. This is statistically significant and again supports previous workers who indicate antegonial notching is occurring in this area.

DENTAL ANALYSIS

Various observers (Eastham 1971, and Lindskog 1967) have suggested that the Milwaukee Brace will lead to malocclusions. No report yet, shows the incidence of malocclusions in Milwaukee Brace patients. In this Scoliosis group. 28 out of 29 patients or (96.6%) had malocclusions. The class 1 occlusion,

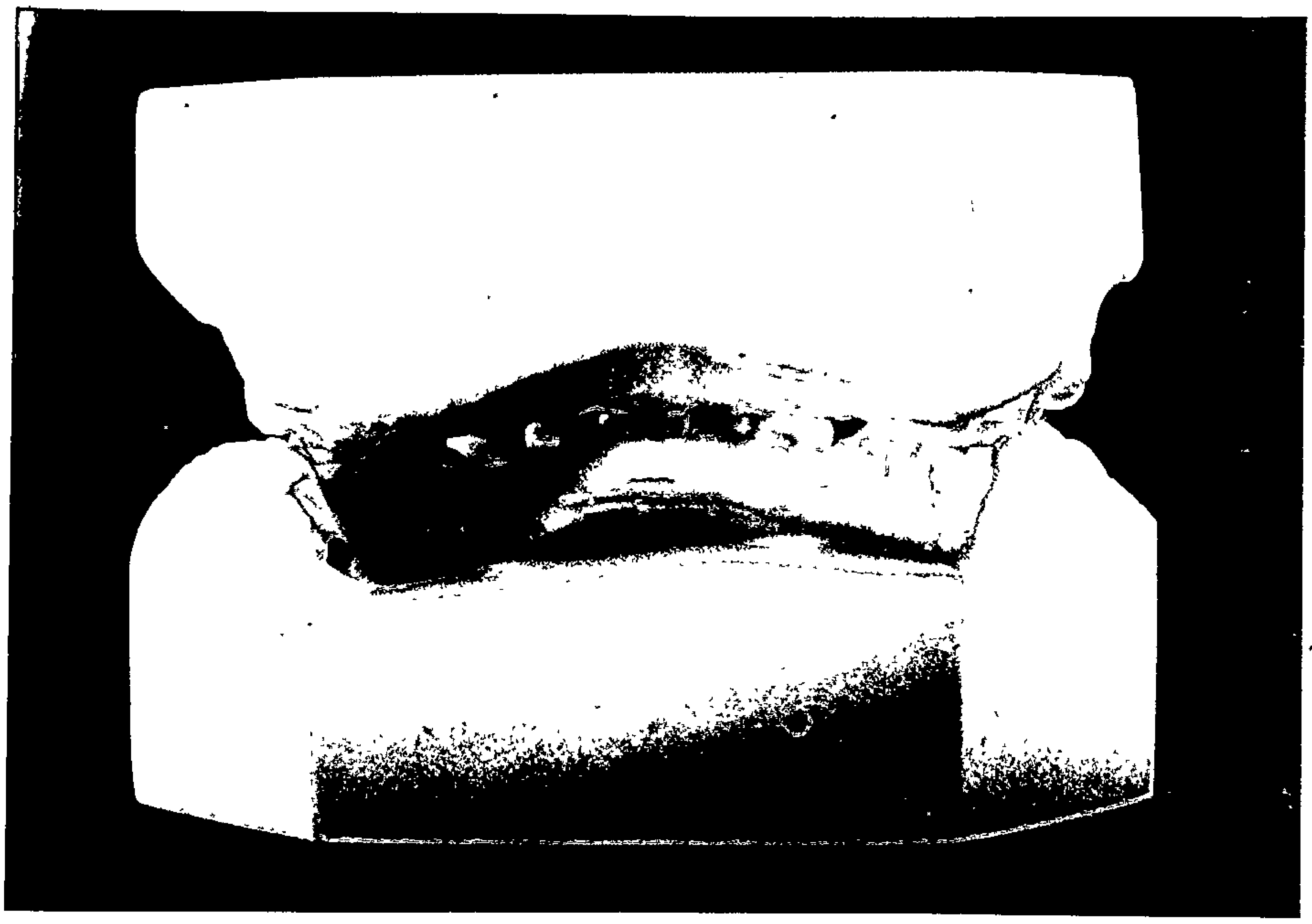


Fig. 44

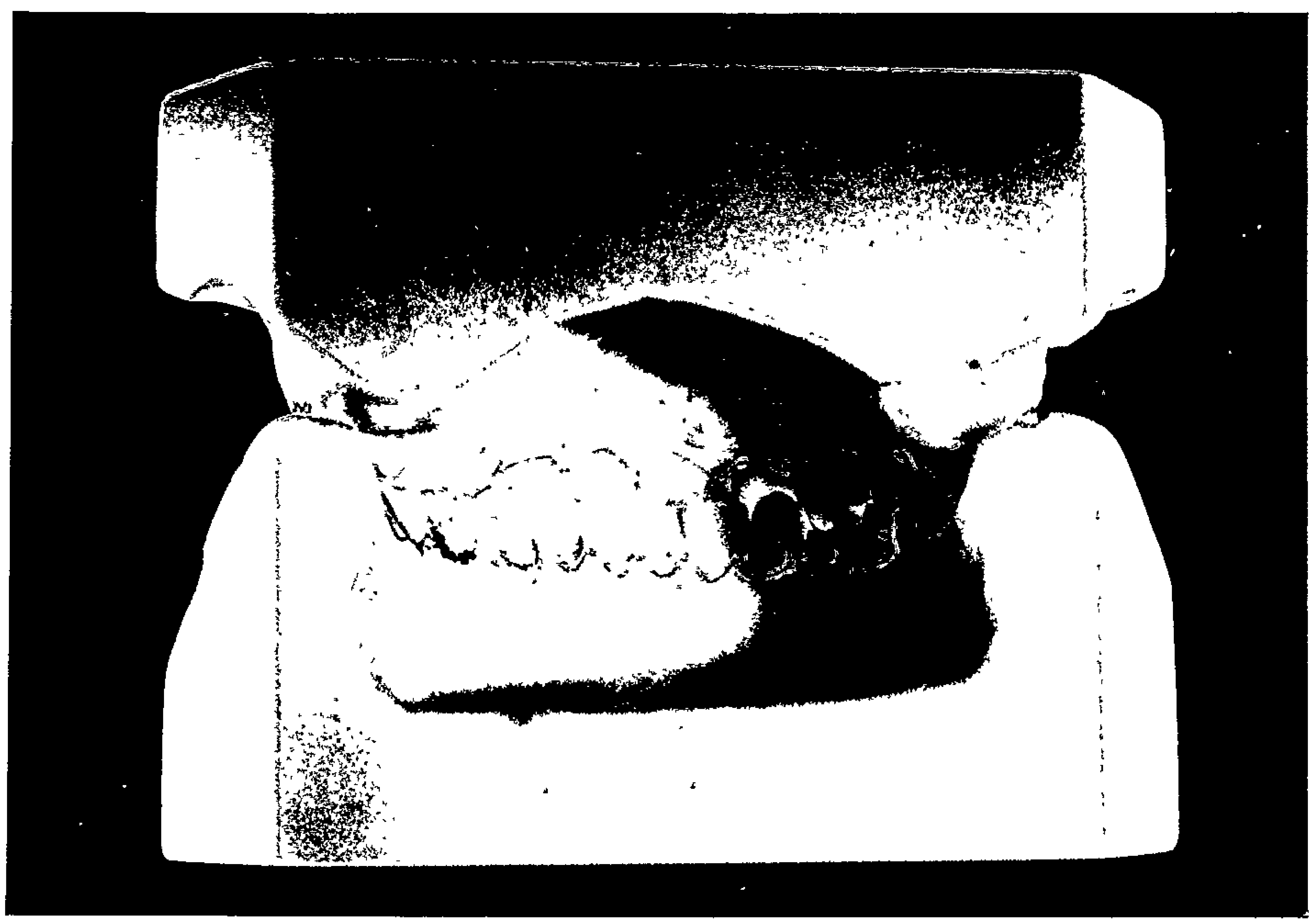


Fig. 45

Figs. 44, 45.

Posterior view of Study Models of patient M.C. (above) and a patient with normal occlusion of same age and sex (below).

Note reduced tongue space, and flattening of the palatal plane in the Milwaukee Brace patient M.C.

showed proclination of the incisor teeth (IMPA 113^{o}) and(U1 to SN 122^{o}).

No previous dental records were available of the Scoliosis group. Therefore, the exact number that developed malocclusions as a result of Milwaukee Brace therapy could not be determined. However, it is most unlikely that such a high percentage of patients had malocclusions prior to the Milwaukee Brace therapy. A common report from parents, was that their child's teeth were 'all right' before the brace was applied. One of the first changes noticed by parents during Milwaukee Brace therapy was spacing and proclination of anterior teeth. This high percentage of Milwaukee patients with malocclusions, suggest that some form of preventative orthodontic therapy should be commenced prior to final fitting of the brace. Particularly if there is no substantial reversal of dental changes to be expected after cessation of brace use.

Though proclination and linear dimensions return to their original state (Hodges 1965), the return of the teeth to a healthy occlusion, without orthodontic treatment, is doubtful.

The high incidence of Class 11 Division 2 malocclusions and deepening bite, also indicates that compression of the lower facial structures is occurring. This high incidence of Class 11 Division 2 malocclusion is not unexpected when considering the direction of the force of the Milwaukee Brace against the mandible.

The high incidence of spacing of anterior teeth, in the experimental group (15), suggests that this upward compression of facial structures does lead to changes in positioning of individual teeth in the alveolus.

In previous studies lower molar depression has been reported to be larger than upper molar depression. Alexander's (1966) Milwaukee Brace group showed upper molar depression of 1.3mm. and lower depression of 2.2mm.

The findings of this study, support these previous findings. The mean difference in lower molar depression was 3.6mm. If the alveolus around maxillary teeth is no different than that around the mandibular teeth, why this large difference between upper and lower molar depression? It could be due in part to resorption along the lower border of the mandible.

Re-directin of maxillary and mandibular growth, as a result of Milwaukee Brace therapy has been recorded. (Cutler 1972), (Thørs 1964). A follow-up study would be necessary to indicate an alteration in growth trend in this study.

The question that puzzles orthodontists is: Why do the dental and facial structures recover after Milwaukee Brace removal and yet in "orthopaedic orthodontics" (e.g. chin cap and headgear), this recovery is not apparent? It places some doubt on whether the orthopaedic force, applicable to orthodontics (Graber, 1968), is in fact affecting the skeletal pattern. It may be a heavy force moving teeth through bone.

The Milwaukee Brace produces an orthopaedic force (4-6lbs), against the mandible. However, only 2.1% of the Scoliosis group had a facial skeletal 11 patterns compared to 51.7% who had (Angle) Class 11 malocclusions. Further comparison with the Tamworth Survey shows the normal population would have 17.4% with Class 11 (Angle) malocclusion.

This large percentage with Angle's Class 11 malocclusion in the Experimental Group is difficult to explain. It could be the force from the Milwaukee Brace acts in a postero-superior direction. It could be the spacing and flaring of the anterior teeth in the upper arch (48.2% had spacing in the upper anteriors, 0.34% had spacing of the lower anteriors), resulting in mesial drifting of the upper molars, thus allowing the development of Class 11 molar relationship.

Contrary to expectation, in both this and previously reported studies, it is noted that no patient has reported temporomandibular joint disturbances. Disturbances, such as pain and joint discomfort resulting from large forces, which produce mandibular repositioning and heavy, functional contacting teeth, were not observed.

This series of complex facial and dental changes as a result of the Milwaukee Brace, shows the remarkable adaptability of the physiology of the oral mechanism.

A general impression, was that those patients who were keenly interested in Milwaukee Brace therapy, and understood how the brace would 'stretch and straighten' their spine, showed better co-operation and better results in spinal curvature correction.

(V) SUMMARY AND CONCLUSIONS

A group of 29 Milwaukee Brace Scoliotics were compared with 29 pre-treatment orthodontic patients, who were matched for sex and age range.

Medical data was collected on the length of time these scoliosis patients wore the brace and its effect on the spinal curvature. Dental data, in the form of cephalometric measurements, incidence and type of malocclusion were recorded.

Cephalometric comparision revealed the Scoliosis (experimental) group's linear measurements were smaller than the pretreatment orthodontic group. The vertical linear measurements of the jaws were significantly reduced, indicating that the Milwaukee Brace does compress the facial structures, particularly the lower facial structures.

The dental data revealed the Scoliosis (experimental) group who had worn the Milwaukee Brace between three months and four years, that 96.6% had malocclusions. The predominance of malocclusion was Class 11 Division 2. The overbite comparison showed this group had 9 patients with deep bite and 12 with very deep bite; the control group showed 5 with deep bite and 8 with very deep bite. The higher incidence of deep, or very deep, bite and Class 11 Division 2 malocclusions is not unexpected, since an orthopaedic force (4-6lbs.) is acting against the lower border of the mandible in an upwards direction.

The possible less-detrimental effects on the dental occlusion by the recently developed throat mould; in place of the chin pad used with the Milwaukee Brace, remains to be evaluated.

Spacing between teeth, particularly the upper anteriors has been a common finding in Milwaukee Brace patients. The Scoliosis (experimental) group had 15 patients with spacing of the upper anteriors, while the control group had 7 patients with spacing of their upper anteriors.

No pretreatment dental records of the Scoliosis group were available. However, the large percentage of Milwaukee Brace patients who had malocclusion, indicates some orthodontic measures should be employed while under Brace Treatment. (Appendix A).

The change in cephalometric linear measurements, whether permanent or completely recoverable, will only be determined by future studies. However, it appears from this and previous studies, Milwaukee Brace Therapy and compression of facial structures are concomittant.

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APPENDIX A

AN ORTHODONTIC PROCEDURE FOR THE TREATMENT OF MILWAUKEE BRACE PATIENTS

Introduction

The large percentage of Milwaukee Brace patients who may require orthodontic treatment could be as high as 96% if the experimental group in this study is representative of all Milwaukee Brace patients.

Ideally, malocclusions which are evident before Milwaukee Brace Therapy, should be corrected to obtain a more stable occlusion. At least minor corrections of short duration sufficient to produce a more stable occlusion should be considered. Even if a stable occlusion exists prior to brace therapy, preventative measures in the form of intraoral splinting should be carried out for the following reasons:

(a) To bind the maxilla and mandible to form a more stable distraction point for the mandibular pad of the Milwaukee Brace.

(b) To prevent the development of malocclusions by holding the teeth in their original positions.

Considerations in intraoral splinting

In Milwaukee Brace therapy, like Orthodontic therapy, patient co-operation is essential. To place an intraoral splint in the mouth 18-20 hours per day (Bunch, 1961) and at the same time tolerate a bulky leather/metal brace may be asking too much of patients.

The following should be considered before intraoral splinting is undertaken:

(1) Patient co-operation and motivation: it is essential to have both. A few scoliotics suffer mental disease, and in such cases intraoral splinting is usually difficult to accomplish.

(2) Properties of the intraoral splint has the following characteristics.

It should,

(a) Bind the upper and lower occlusion firmly to form a stable unit of resistance.

(b) Be readily accepted by the patient.

(c) Be easily kept clean and not unsightly in appearance.

(d) Be comfortable and not bulky.

Bunch (1961), listed numerous materials that have been tried in the construction of intraoral splints, wax, rubber, vulcanite, acrylic and metal. After numerous designs and modifications, still no appliance today seems ideal. In fact, there is no obvious orthodontic treatment procedure for Milwaukee Brace patients.

Roth (1969), claimed his modified monobloc appliance had the following advantages: It allowed the patient to speak and breathe while wearing the appliance and was cosmetically acceptable. This acrylic appliance, however, covered only the occlusal and lingual surfaces of the teeth. Godfrey and Spence (1971), used a semi-rigid mouthguard material to construct an intraoral splint for a five year old Milwaukee Brace patient. In design, it covered half the clinical crowns of all teeth present and was well tolerated by the patient. However, as recorded by Eastham (1971), such semi-rigid (Thermoplastic vinyl) materials, in long term use allows for collapse of vertical facial height. The main advantage of this material (Bunch, 1961), for intraoral splinting is in short term Milwaukee Brace therapy.

Eastham (1971), investigations on intraoral splints used with the Milwaukee Brace, found of the Processed acrylic, Vitallium splint, Thermoplastic vinyl splint, Silastic splint, Impak plastic splint, and fixed-orthodontic banding, that the processed acrylic appliance was the most successful in stabilizing the dental occlusion, and led to the least reduction in vertical facial dimensions.

Splint Construction

Seven Milwaukee Brace patients from the Scoliosis Clinic at Royal Prince Alfred Hospital, Sydney, were considered suitable for intraoral splinting of the following design. Maxium interlocking of the occlusion was obtained by covering all tooth surfaces, except the interproximals.

The appliance was waxed up on centric mounted, articulated models, including 3-4mm. of inter-occlusal space. In most cases it was possible to place lateral and or anterior airways. (Fig. 46,47).

The clear processed acrylic allowed for the use of thin sections of material thus making it less bulky and pleasing in appearance than thermoplastic material.

Though the oral hygiene problem would be increased with complete tooth coverage, it was felt, the patient being under constant supervision, this could be controlled.

The patients were instructed to wear the splint at night or if they lay down during the day. It was to be worn for 2-3 hours at some time during the day also. (fig. 48)

After one week adaptation, all patients had readily accepted this appliance and found it comfortable. Initially four patients reported sore teeth, and one patient had difficulty retaining the appliance in position during sleep.

It was felt unwise to commence orthodontic treatment in the form of full fixed banding in Mulwaukee Brace patients, due to the orthopaedic force acting against the mandible.

Due to the long term nature of studies involving scoliosis, and evaluation of this intraoral splint may take 4-5 years.

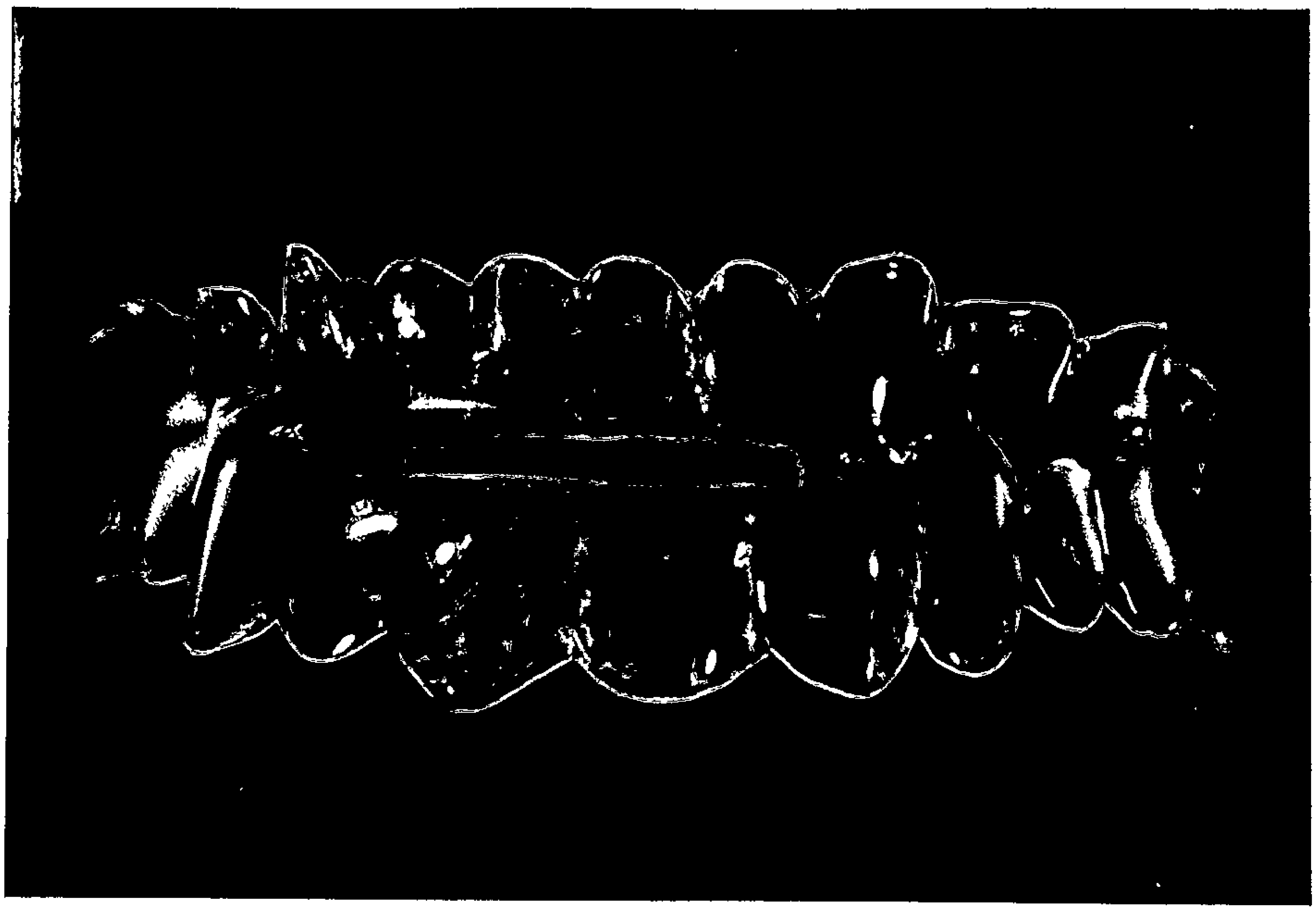

Fig. 46

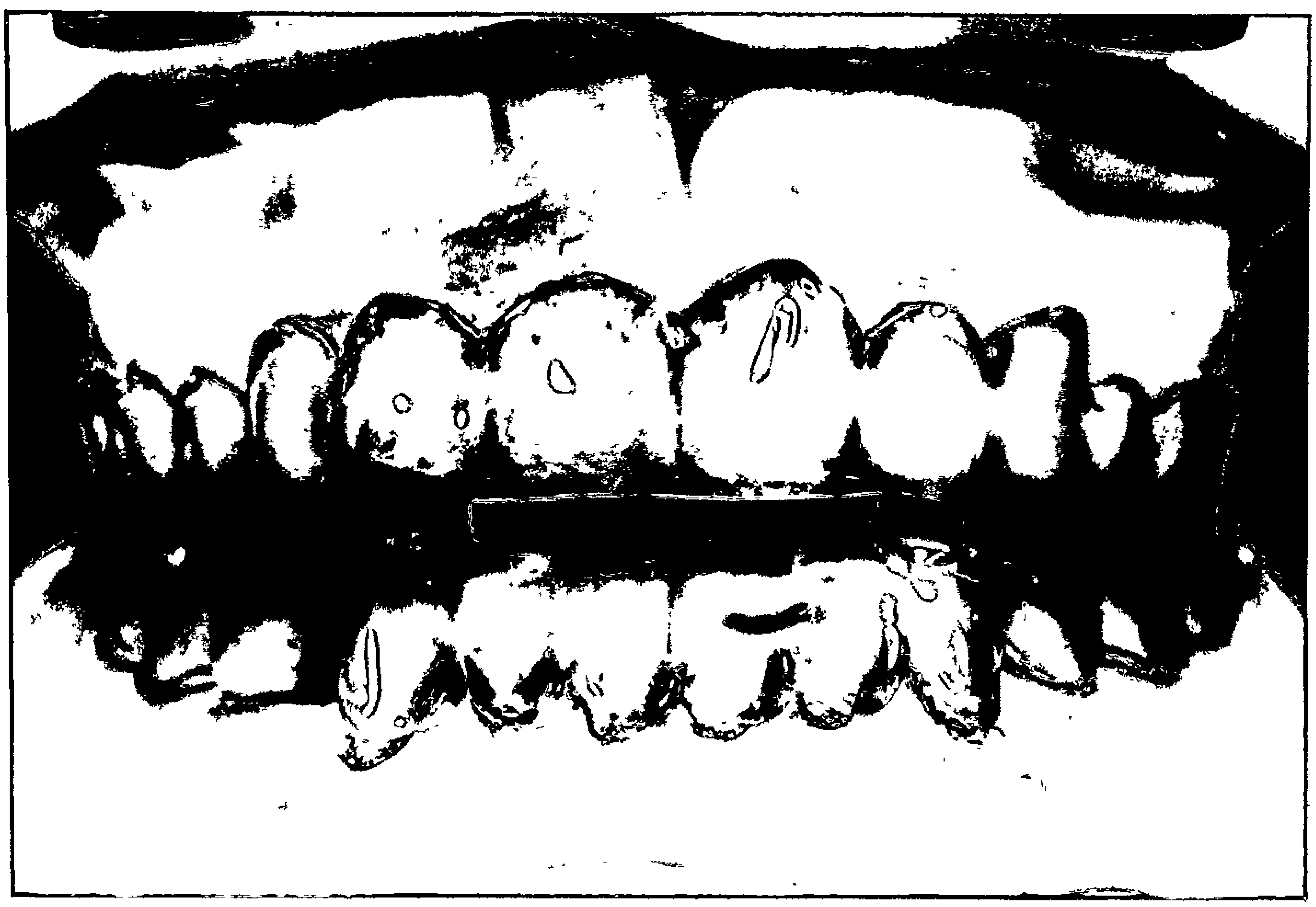

Fig. 47

Figs. 46, 47. *Occlusion-Locking Splints. Constructed from processed, clear acrylic, showing maximum coverage of all tooth surfaces and an anterior oral airway.*

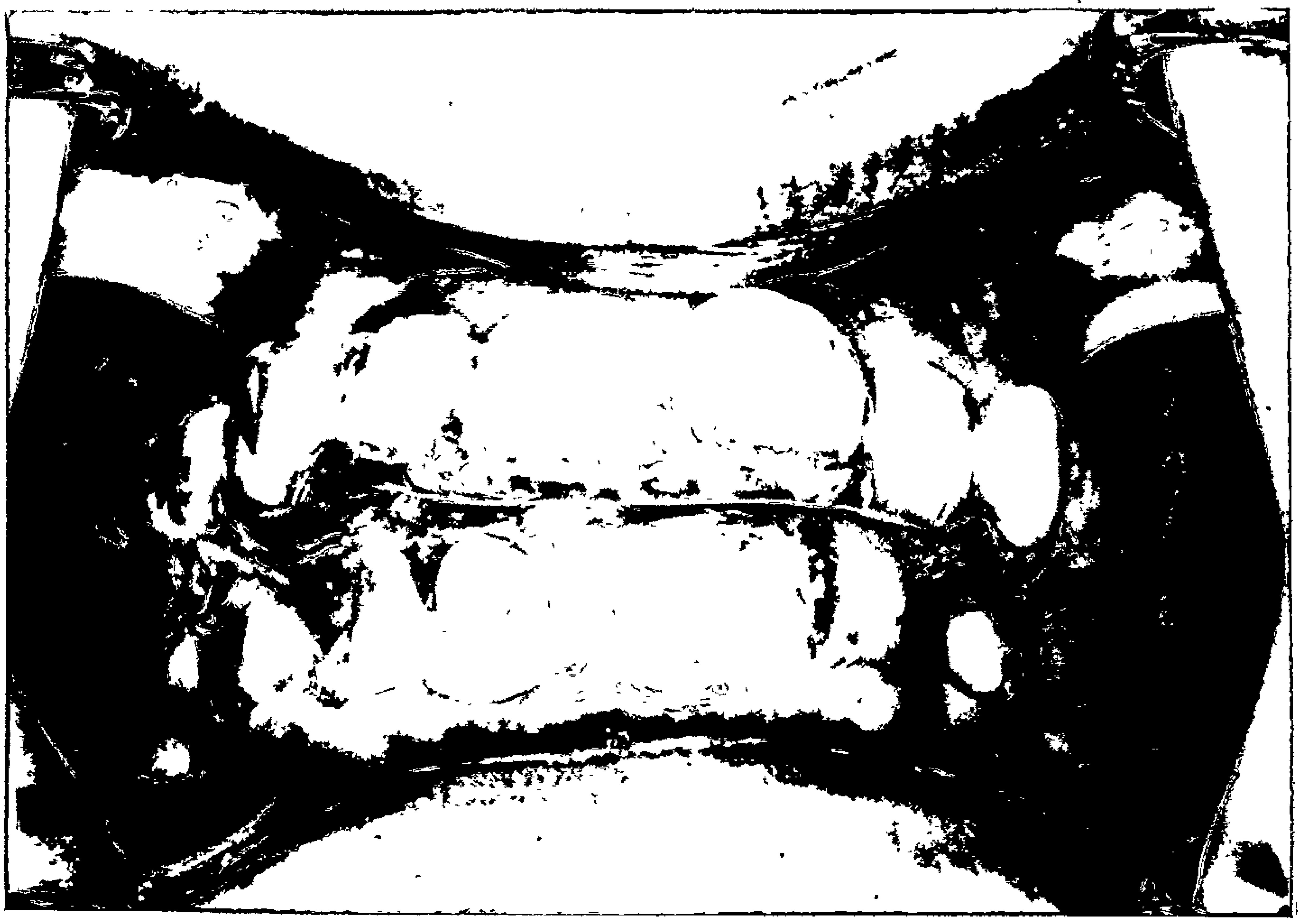

Fig. 48

Occlusion-locking splint as worn by patient 'MM'. Having anterior and lateral airways.

APPENDIX B

TABLES VII and VIII

TABLE VII RECORDED (INDIVIDUAL) CEPHALOMETRIC LINEAR AND ANGULAR MEASUREMENTS OF THE SCOLIOSIS GROUP

MEASUREMENTS	MM	JT	VH	SL	JS	DW	MK	LS	DF	BP	KR	SE	JM
Total Anterior Face Height (T.A.F.H.)	91	110.5	100	93	107	112	107	86	105.5	93	96	115	109
Upper Anterior Face Height (U.A.F.H.)	37	50	48	40	51	50	48	42.5	48.5	40	43	51.5	53
Lower Anterior Face Height (L.A.F.H.)	54	60.5	52	53	56	62	59	43.5	57	53	53	63.5	56
Posterior Face Height (mm)	36	42	33	33	40	39	35	34	32	33	28	39	34
Lower Molar Height (mm)	23	30	22	23	24	26	27	21	28	25	23	31	29
Upper Molar Height (mm)	16	21	18	20	22	19	18	15.5	19	16	17	23	19
SNaPog (degrees)	86	78	72	83	82	80	81.5	83.5	80	85	81	80	77
MP to Sn (degrees)	23	30	35	25	32	32	31	25	30	30	34	29	31
U1 to L1 (degrees)	103	164	105	126	122	135	119.5	159	126	118	110	102	110
I.M.P.A. (degrees)	103	90	112	98	90	81	96.5	83	96	94	103	109	107
U1 to Sn (degrees)	135	77.5	118	112	116	113	113	94	109	119	109	120	112
ANB (degrees)	0	+7	+4	+3	+1	+2	+3	+5	+3.5	+3	+6	0	+5
SNa (degrees)	83	82	75	82	81	75	82	85	81.5	87	87	78	81
Gonial (degrees)	116	115	127	124	133	124	121	133	126	127	122	116.5	120

MEASUREMENTS	CR	YF	JP	PR	PC	JM	MC	CT	JS	KS	KL	CB	JM	BW	TM	RP
Total Anterior Face Height (T.A.F.H.)	105	102	114	101	102	90	94	110	111.5	95	96	100	100	104	111	99
Upper Anterior Face Height (U.A.F.H.)	50	46	52	46	49	35	44	48	48	40	42	43	42	41	50	43
Lower Anterior Face Height (L.A.F.H.)	55	56	62	55	53	55	50	62	63.5	55	54	57	58	63	61	56
Posterior Face Height (mm)	32	27	48.5	34	29	34	32	36	39	32	34	36	28	34	34	42
Lower Molar Height (mm)	21	28	31	31	22	24	23	26	30	23	23	25	22	27	28	26
Upper Molar Height (mm)	22	17	21	16	17	12	15	20	24	13	16	18	18	19	16	22
SNaPog (degrees)	79	77	82	73	87	84	82	85	82	71	82	82	73	76	78	77
MP to Sn (degrees)	34	35	26.5	34	39	21	27	30	33	42	27	33	45	33	35	27
U1 to L1 (degrees)	125	115	130	118	134	128	65	119	110	150	138	130	136	141	132	99
I.M.P.A. (degrees)	89	103	92.5	101	77	100	132	90	97	74	87	90	82	91	89	113
U1 to Sn (degrees)	113	109	112	107	108	117	137	120	120	95	106	106	96	93	103	122
ANB (degrees)	+2	+10	-2	+5	+1	+5	+2	+0	+2	0	+3	+2	-2	+5	-1	+2
SNa (degrees)	77	85	78	77	76	76	81	84	82	69	84	82	71	80	76	78
Gonial (degrees)	128	124	123	123	125	125	120	126	127	131	126	129	139	131	127	121

TABLE VIII RECORDED (INDIVIDUAL) CEPHALOMETRIC LINEAR AND ANGULAR MEASUREMENTS OF THE PRE-TREATMENT ORTHODONTIC GROUP

Measurements		KD	MD	GH	MV	JE	RD	PA	RS	SN	NS	LF	DM	WB	EG
Total Anterior Face Height (T.A.F.H.)	(mm)	122	116	102.5	117	111	112	108	101	114	107	116	115.5	115	111
Upper Anterior Face Height (U.A.F.H.)	(mm)	49	50.5	50	58	49	53	49	43	54	47.5	56	56	50	48
Lower Anterior Face Height (L.A.F.H.)	(mm)	73	65.5	52.5	59	62	59	59	58	60	59.5	60	59.5	65	63
Posterior Face Height	(mm)	51	37	43	42	47	43	44	34	47	42	52	39	40	42
Lower Molar Height	(mm)	29	27	28	28.5	32	25	28	23	30	29	30	27	28	30
Upper Molar Height	(mm)	21	19	16	18	18	21	23	17	20	18.5	24	21	18	21
SNaPog	(degrees)	75	76.5	80	77	87	77	77	72	75	77	82	78	77.5	76
MP to Sn	(degrees)	42	39	30	30	27	34	28	39	35	30	27	37.5	37	34
U1 to L1	(degrees)	127	116	133	126	113	117	121	146	113	142	125	149	118	133
I.M.P.A.	(degrees)	83	92	77	102	95	102	99	87	98	93	102	78	87	91
U1 to Sn	(degrees)	106	112	119	104	124	107	121	88	114	94	105	97	109	103
ANB	(degrees)	+3	+6	+2.5	+5	+6	+6	+3	+8	+1.5	+4	+4	+3	+6	+1
Sna	(degrees)	76	82	79	82.5	87	80	79	80	77	79	82.5	79	82	76.5
Gonial	(degrees)	137	130	128	118	140	142	126	144	127	127	124	129	133	124

Measurements		JP	KN	DO	KP	SH	FP	EM	DM	EF	CD	MP	RL	RD	RH	CA
Total Anterior Face Height (T.A.F.H.)	(mm)	130	113	116	114	122	113	115	119	122	113	107	117	117	103	127
Upper Anterior Face Height (U.A.F.H.)	(mm)	57	49.5	48	47	53	47.5	47.5	51	50	50.5	45	46.5	51	45	54
Lower Anterior Face Height (L.A.F.H.)	(mm)	73	54	68	57	69	65.5	67.5	68	72	62.5	62	70.5	66	58	73
Posterior Face Height	(mm)	45	39	41	36	43	35	45	47	39	44	43	45	36	37	40
Lower Molar Height	(mm)	31	30	31	25	32	26	35	33	32	32	30	29	26	28	28.5
Upper Molar Height	(mm)	23	22	22	19	23	20	22	25	24	18	20.5	26	20	22	24
SNaPog	(degrees)	78	88.5	83.5	71	79	76	82	81	80	83	87	78	83	78	78.5
MP to Sn	(degrees)	37	36	34	50	39	45	32	30.5	35	28	23.5	36	41	32	46
U1 to L1	(degrees)	130	137	132	155.5	128	129	117	80.5	133	142	117	130	110	114	131
I.M.P.A.	(degrees)	90	91	88	73	92	89	97	101.5	89	92	104	85	91	105	73
U1 to Sn	(degrees)	104	96	105	83	102	97	114	105	102.5	99	115	110	118	103	108
ANB	(degrees)	+3	+4	+2	+3	+1	+5	+4	+3.5	+3	+4	+6	+2	+1	0	-2
Sna	(degrees)	81	81.5	83.5	75	77	81	85	80.5	83	87	91.5	80	68	76	76
Gonial	(degrees)	130	130	124	139	129	139	126	126	121	124.5	126	127	139	127	137