MORPHOLOGICAL DIFFERENCES IN CRANIOFACIAL STRUCTURE BETWEEN JAPANESE AND CAUCASIAN SUBJECTS

THESIS SUBMITTED BY

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ABSTRACT

Morphological differences in the craniofacial structure between Japanese and Caucasians were examined using lateral cephalograms. Although previous investigators have attempted similar studies, these have not examined totally the craniofacial patterns seen in both normal subjects and those with malocclusions. This project addressed this issue by considering Class I normal occlusion, Class II malocclusion and Class III malocclusion.

In the Class I comparison, the Japanese had significantly shorter anterior and posterior cranial base lengths, longer anterior and posterior facial heights and more proclined upper incisors compared to the Caucasians. In the Class II comparison, the Japanese had a significantly shorter anterior cranial base length, a more obtuse articular angle, a steeper mandibular plane angle and more proclined lower incisors compared to the Caucasian sample. In the Class III comparison, the Japanese had a significantly shorter anterior cranial base length, a longer anterior facial height, a more obtuse gonial angle and more proclined upper incisors compared to the Caucasian group.

In summary, it was noted that the Japanese samples had a shorter cranial base and an excessive vertical development, such that these might be common racial features in the Japanese population. The Japanese had a brachycephalic cranium and a dolichocephalic mandible, such that the craniofacial skeleton of the Japanese could not be categorized into the classifications based on the Caucasian populations. The craniofacial skeleton of the Japanese differed from that of the Caucasians, such that the racial differences should be considered when planning orthodontic treatment in today's multiracial society.

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CHAPTER 1

General Introduction

(Athanasiou, 1995)

1.1 Introduction of Cephalometric Radiography

1.1.1 History

A scientific approach to the scrutiny of human craniofacial patterns was first initiated by anthropologists and anatomists who recorded the various dimensions of ancient dried skulls. The measurement of the dry skull from osteological landmarks was called craniometry. The measurement of the head of a living subject from the bony landmarks is called cephalometry.

The discovery of X-rays by Roentgen in 1895 revolutionized medicine and dentistry and facilitated the accurate study of craniofacial growth and development. The measurement of the head from the shadows of bony and soft tissue landmarks on the radiographic image became known as roentgenographic cephalometry (Krogman and Sassouni, 1957). Broadbent (1931) and Hofrath (1931) simultaneously presented a standardized cephalometric technique using a high powered X-ray machine and a head holder called a cephalostat or cephalometer.

The lateral cephalometric radiograph (cephalogram) itself is the product of a two-dimensional image of the skull in lateral view, enabling the relationship between teeth, bone, soft tissue and empty space to be scrutinized both horizontally and vertically. It has influenced orthodontics in three major areas: (1) in morphological analysis, by evaluating the sagittal and vertical relationships of the dentition, the facial skeleton and the soft tissue profile, (2) in growth analysis, by taking two or more cephalograms at different time intervals and comparing the relative changes, and (3) in treatment analysis, by evaluating alterations during and after therapy.

1.1.2 Technical Aspects

The basic components of the equipment for producing a lateral cephalogram (Frommer, 1978; Barr and Stephens, 1980; Wuehrmann and Manson-Hing, 1981; Manson-Hing, 1985; Goaz and White, 1987) are: (1) an X-ray apparatus, (2) an image receptor system, and (3) a cephalostat.

1.1.2.1 X-ray Apparatus

The X-ray apparatus comprises an X-ray tube, transformers, filters, collimators and a coolant system, all encased in the machine housing. The X-ray tube is a high-vacuum tube that serves as a source of the X-rays. The three basic elements that generate the X-rays are a cathode, an anode, and the electrical power supply (Fig. 1.1). The cathode is a tungsten filament surrounded by a molybdenum focusing cup. The tungsten filament serves as a source of electrons. The anode is stationary and comprises a small tungsten block embedded in a copper stem (the target), which stops the accelerated electrons, whose kinetic energy causes the creation of photons. The X-ray photons emerging from the target are made up of a divergent beam with different energy levels, and only X-rays with sufficient penetrating power are allowed to reach the patient.

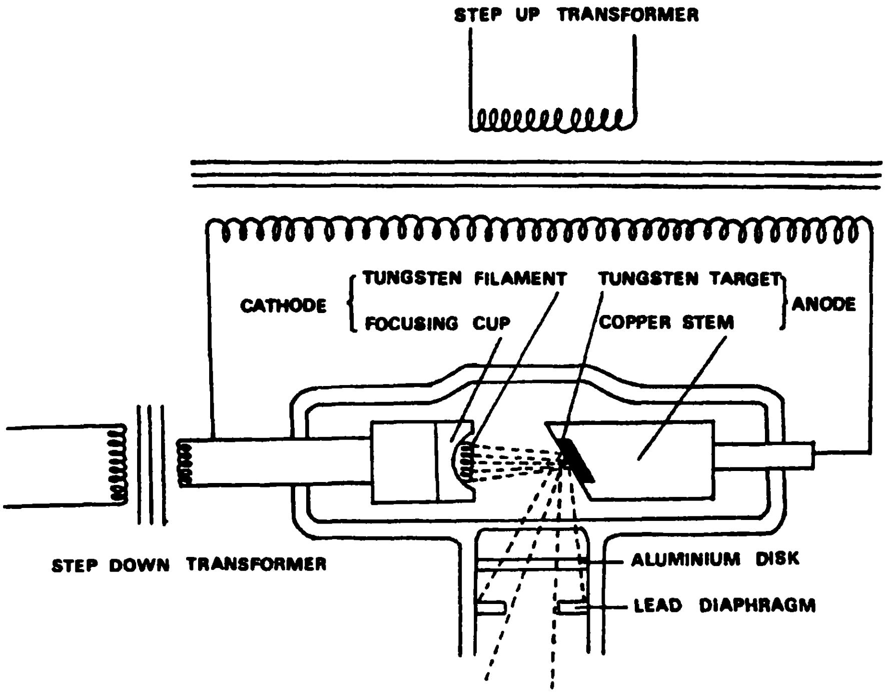

Fig. 1.1 X-ray tube with basic elements; cathode, anode, and electrical power supply (Athanasiou, 1995).

1.1.2.2 Image Receptor System

An image receptor system records the final product of X-rays after they pass through the subjects. The extraoral projection including the lateral cephalometric technique requires a complex image receptor system that consists of an extraoral film, intensifying screens, a cassette, a grid, and a soft tissue shield. When the silver halide crystals are exposed to the radiation, they are converted to metallic silver deposited in the film, thereby producing a latent image. This is converted into a visible and permanent image after film processing.

1.1.2.3 Cephalostat

The use of a cephalostat, also called a head-holder or cephalometer, is based on the same principle as that described by Broadbent (1931). The patient's head is fixed by two ear-rods that are inserted into the external auditory meati (EAM) such that the upper borders of the EAM rest on the upper parts of the ear-rods. The head, which is centred in the cephalostat, is oriented with Frankfort plane parallel to the floor and the mid-sagittal plane vertical and parallel to the cassette. The system can be moved vertically relative to the X-ray tube, or the image receptor system and the cephalostat as a whole can be moved to accommodate sitting or standing patients. The projection is taken when the teeth are in centric occlusion and the lips in repose. In Japan, the distance from focus to midsagittal plane is usually 150cm and from midsagittal plane to film is 15cm, but different distances have been also reported. It is usual for the left side of the head to face the cassette.

1.1.3 Image Quality

Image quality is a major factor influencing the accuracy of cephalometric analysis (Franklin, 1952; Krogman and Sassouni, 1957; Frommer, 1978; Barr and Stephens, 1980; Wuehrmann and Manson-Hing, 1981; Goaz and White, 1987). An acceptable diagnostic radiograph is considered in the light of two groups of characteristics: (1) visual characteristics, and (2) geometric characteristics.

1.1.3.1 Visual Characteristics

The visual characteristics, density and contrast, are those that relate to the ability of the image to demonstrate optimum detail within anatomical structures and to differentiate between them by means of relative transparency. Density is the degree of blackness of the image when it is viewed in front of an illuminator or viewing box. Contrast is the difference in densities between adjacent areas on the radiographic image. Image density and contrast can be affected by film processing. When using an automatic film processor, density and contrast are both controlled by the temperature of the developer and by the developing time.

1.1.3.2 Geometric Characteristics

The geometric characteristics are image unsharpness, image magnification, and sharp distortion. Image unsharpness is classified into three types according to aetiology: geometric, motion and material. Geometric unsharpness is the fuzzy outline in a radiographic image caused by the penumbra. Image magnification is the enlargement of the actual size of the object. Sharp distortion results in an image that does not correspond proportionally to the subject. Image sharpness and magnification are controlled by the manufacturer and the operator. The manufacturer provides the most efficient focal spot size, target-film distance, collimation, and filtration measures so that the maximum X-ray beams with the best size and sharpness are produced. The operator plays a major role in controlling the patient's head position, the object-film distance and the movement of the X-ray tube.

1.2 Cephalometric Landmarks (Miyashita, 1996)

A lateral cephalogram is one of the orthodontic records that provides information about the sagittal and vertical relations of the craniofacial skeleton, the soft tissue profile, the dentition, the pharynx, and the cervical vertebrae. These structures and their relationships to each other are scrutinized by means of linear and angular measurements as well as by the use of ratios based on the various cephalometric landmarks. These cephalometric landmarks should be identified; errors in their identification can be minimized by a thorough knowledge of the anatomy of the skull and by an awareness of the close correspondence between gross anatomy and radiographic appearance of each structure and the detailed criteria for identification of each anatomical cephalometric point.

The representative cephalometric landmarks used in the present study should be described (Fig. 1.2).

1. **A** – Point A – the deepest midline point on the premaxilla between the anterior nasal spine and prosthion (Downs, 1948).
2. **ANS** – Anterior nasal spine – the most anterior point of the nasal floor; tip of the premaxilla on midsagittal plane (Sassouni, 1971).
3. **Ar** – Articulare – the point of intersection of the dorsal contour of the process articularis mandibulae and os temporale (Graber, 1975).
4. **B** – Point B – the deepest midline point on the mandible between infradentale and pogonion (Downs, 1948).
5. **Ba** – Basion – the most inferior point on the anterior margin of the foramen magnum in the midsagittal plane (Graber, 1975).
6. **G** – constructed Gonion – point of intersection between the mandibular line and the ramus line (Bjork, 1960).
7. **Gn** – Gnathion – the midpoint between Pog and Me located at the intersection of the facial line and the mandibular plane (Sassouni and Setareanos, 1974).
8. **Go** – anatomical Gonion – the most posterior inferior point at the angle of the mandible (Moyers, 1973).
9. **Ii** – Incision inferius – the incisal point of the most prominent medial mandibular incisor (Bjork, 1947).

10. **Is** – Incision superius – midpoint of the incisal edge of the most prominent upper central incisor (Bjork, 1960).
11. **LIA** – Lower incisor apex – the root apex of the most prominent lower incisor (Bhatia and Leighton, 1993).
12. **LMT** – Lower molar mesial cusp tip – the anterior cusp tip of the mandibular first molar (Riolo *et al.*, 1974).
13. **Me** – Menton – the most inferior point on the symphysis of the mandible in the median plane (Broadbent *et al.*, 1975).
14. **N** – Nasion – craniometric point where the midsagittal plane intersects the most anterior point of the nasofrontal suture (Broadbent *et al.*, 1975).
15. **PNS** – Posterior nasal spine – the most posterior point at the sagittal plane on the bony hard palate (Riolo *et al.*, 1974).
16. **Pog** – Pogonion – the most anterior point on the symphysis of the mandible (Graber, 1952).
17. **S** – Sella – the centre of the pituitary fossa (Graber, 1975).
18. **UIA** – Upper incisor apex – the root apex of the most prominent upper incisor (Bhatia and Leighton, 1993).
19. **UMT** – Upper molar mesial cusp tip – the anterior cusp tip of the maxillary first molar (Riolo *et al.*, 1974).

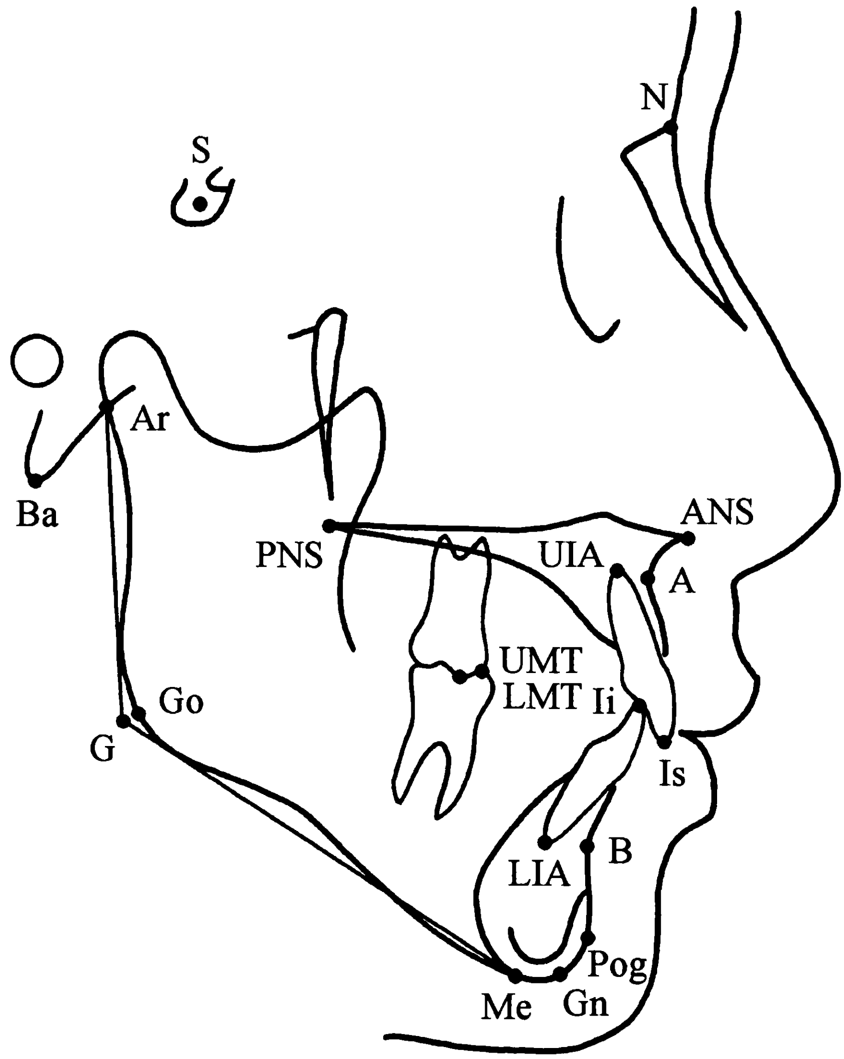

Fig. 1.2 Cephalometric landmarks used in the study.

1.3 Errors of Cephalometric Measurements

Cephalometric measurements on radiographic images are subject to errors that may be caused by: (1) radiographic projection errors, (2) errors within the measuring system, (3) errors in landmark identification, and (4) errors in patient positioning.

1.3.1 Radiographic Projection Errors

During the recording procedure, the object as imaged on a conventional radiographic film is subjected to magnification and distortion.

1.3.1.1 Magnification

Magnification occurs because the X-ray beams are not parallel with all the points in the object to be examined. The magnitude of enlargement is related to the distances between the focus, the object, and the film (Adams, 1940; Brodie, 1949; Hixon, 1960; Bjork and Solow, 1962; Salzmann, 1964). The use of long focus-object and short object-film distances has been recommended in order to minimize such projection errors (Franklin, 1952; Nawrath, 1961; Aken, 1963).

1.3.1.2 Distortion

Distortion occurs because of different magnifications between different planes. Although most of the landmarks used for cephalometric analysis are located in the midsagittal plane, some landmarks and many structures that are useful for superimposing radiographs are affected by distortion, owing to their location in a different depth of field. Landmarks and structures not situated in the midsagittal plane are usually bilateral, thus giving a dual image on the radiograph. The problem of locating bilateral structures subjected to distortion can to some extent be compensated for by recording the midpoints between these structures.

1.3.2 Errors within the Measuring System (Turner and Weerakone, 2001)

The analysis of cephalometric lateral skull radiographs is critically dependent on the accurate location of carefully defined anatomical and constructed landmarks. Errors in landmark identification, both systematic and random, are a significant source of error (Baumrind and Frantz, 1971a; Midtgard *et al.*, 1974; Cohen, 1984; Houston *et al.*, 1986), so that the methodology used to identify and record landmarks must be meticulous.

Three techniques are commonly used to identify and record landmarks in cephalometric studies. These are:

1) Overlay tracing of the lateral skull radiograph on an X-ray viewer, followed by direct measurement of cephalometric lines and angles on the tracing paper using a ruler and protractor.

2) Overlay tracing of the radiograph to identify anatomical and constructed points followed

by transfer of the tracing to a dizitiser linked to a computer.

3) Direct digitisation of the lateral skull radiograph using a digitiser linked to a computer.

Several studies have examined the accuracy and reproducibility of landmark identification using these different methods. Direct digitisation of radiographs is reported to be most reproducible and therefore the most accurate method (Richardson, 1981; Sandler, 1988), although the difference between methods is small and statistically significant in only a few instances.

Compared to other methods, direct digitisation of radiographs involves fewer stages to record landmarks, and because the angles and distances are automatically calculated using computer software there is less margin for error (Houston, 1982; Cohen, 1984). However, as Richardson pointed out (Richardson, 1981), this highly accurate measurement technique is not necessarily going to reduce overall landmark error when the points being digitised are poorly defined. Furthermore, the design of a digitiser's cursor can obscure structures peripheral to the landmark of interest and the cross-hairs of the cursor can be difficult to distinguish against a dark background (Houston, 1982). This problem does not occur when digitising a tracing.

Landmark identification using tracing paper and hand instruments compares favourably with the results of digitised X-rays and the results of studies using this method can be considered perfectly valid (Richardson, 1981; Sandler, 1988). Tracing alone was found to produce more reproducible results in certain circumstances: for example, the points Ar and Go can be constructed on a tracing, but only estimated using the digitiser (Sandler, 1988). Other points were easier to visualize and locate when the outline of the structure could be traced first, such as the apex of the upper incisor root (Houston, 1982).

Conversely, taking hand measurements from tracings is by far the most time consuming and tedious method, and carries the possibility of errors caused by misreading the measuring instruments and transcribing the data to a computer (Sandler, 1988).

1.3.2.1 Comparing Methods of Landmark Identification

The results of the investigations mentioned above are not directly comparable owing to the way in which repeat tracings of lateral skull radiographs have been examined and the different approaches used in the statistical analysis of the results.

Where the method of point identification is being compared between successive recordings of the same radiograph, it is appropriate to construct Cartesian axes around the radiograph in order to measure the horizontal and vertical distance of each point from the ordinate and abscissa, respectively. These distances can then be compared between recordings and between methods. This approach is more revealing than comparing the values of cephalometric lines and angles of successive tracings where errors in the vertical or horizontal plane (the envelope of error) can be hidden by the cephalometric analysis (Richardson, 1981).

When the position of landmarks are compared between successive recordings any difference noted (in the horizontal or vertical plane) can range from zero upwards. Negative differences are meaningless, as the researcher will never know the true position of a landmark (Houston, 1982). Plotting the differences on a graph for a series of radiographs would reveal a skewed curve, rather than a normal curve. In his study comparing methods, Sandler (1988) found one-third of the data to be skewed and all kurtosed at the 5% level: nearly two-thirds were significantly kurtosed at the 1% level. The application of parametric statistics to skewed data may not be appropriate and non-parametric techniques should be used (Houston, 1982).

1.3.2.2 The Screenceph Method

In this method the lateral skull radiographs are scanned using a flatbed scanner with a transparency hood. The images are captured at an appropriate resolution using a 256 greyscale palette and stored in a PC. The radiographic images are subsequently opened using cephalometric analysis software and digitised on a 17-inch colour monitor. The landmarks are located using a cross-wire mouse cursor and recorded by clicking a mouse button. The x and y co-ordinates of these points are subsequently used to calculate various angular and linear measurements. This method offers several potential advatages over conventional cephalometric analysis, and with future improvement in image resolution is likely to become comparable to direct digitisation for accuracy of point location.

1.3.3 Errors in Landmark Identification

Landmark identification errors are considered the major source of cephalometric error (Bjork, 1947; Hixon, 1956; Savara *et al.*, 1966; Richardson, 1966, 1981; Carlsson, 1967; Baumrind and Frantz, 1971a; Sekiguchi and Savara, 1972; Gravely and Benzies, 1974; Midtgard *et al.*, 1974; Cohen, 1984). Many factors are involved in this uncertainty. These factors include: (1) the quality of radiographic image, (2) the precision of landmark definition and the reproducibility of landmark location, and (3) the operator and the registration procedure.

1.3.3.1 The Quality of Radiographic Image

In principle, the quality of a radiograph is expressed in terms of sharpness, blur and contrast, and noise (Rossmann, 1969; McWilliams and Welander, 1978; Hurst *et al.*, 1979; Broch *et al.*, 1981; Kathopoulis, 1989). Sharpness is the subjective perception of the distinctness of the boundaries of a structure; it is related to blur and contrast. Blur is the distance of the optical density change between the boundaries of a structure and its surroundings (Haus, 1985). It results from three factors: geometric lack of sharpness, receptor lack of sharpness, and motion lack of sharpness. Geometric lack of sharpness is directly related to the size of the focal spot and to the focus-film distance. Receptor lack of sharpness depends on the physical properties of the film and the intensifying screen. Movement of the object, the tube, or the film during exposure results in image blur. By increasing the electrical current, it is possible to reduce the exposure time, thus reducing the effect of movement.

1.3.3.2 The Precision of Landmark Definition and the Reproducibility of Landmark Location

A clear, unambiguous definition of the landmarks chosen is of the utmost importance for cephalometric reliability. Some investigators (Richardson, 1966; Baumrind and Frantz, 1971a; Broch *et al.*, 1981; Stabrun and Danielsen, 1982; Cohen, 1984; Miethke, 1989) have pointed out that some cephalometric landmarks can be located with more precision than others. Furthermore, the distribution of errors for many landmarks is systematic and follows a typical pattern, some landmarks being more reliable in either the vertical or horizontal plane, depending on the topographic orientation of the anatomic structures along which their identification is assessed (Baumrind and Frantz, 1971a). Errors in landmark identification can be reduced if measurements are replicated and their values averaged. Consecutive evaluation of one cephalogram at random showed that the localization of a landmark is more exact the second time than at the first judgement (Miethke, 1989). The more the replications, the smaller the impact of random error on the total error. Even for purpose of scientific research, if cross-sectional or serial measurements from two groups must be compared, duplicate measurements are sufficient (Miethke, 1989).

1.3.3.3 The Operator and the Registration Procedure

Several studies have pointed out that operator's alertness and training and his/her working conditions affect the magnitude of the cephalometric error (Kvam and Krogstad, 1972; Gravely and Benzies, 1974; Houston, 1983). These parameters influence landmark identification in a fashion directly related to the difficulty of identifying each individual landmark. In cephalometric studies, the error level, specific to the operator, has to be established, if meaningful conclusion is to be drawn from the data presented. The most important contributions to improvement in landmark identification are experience and calibration (Houston, 1983). Another kind of bias can be introduced because of subconscious expectations of the operator when assessing the outcome of the scientific research. Randomisation of record measurements or double blind experimental designs can be used for reducing such bias. After collection, cephalometric measurements should be checked for wild values (Houston, 1983). These values can be expressions of normal variation, but sometimes can be attributed to incorrect identification of a landmark or misreading of an instrument.

1.3.4 Errors in Patient Positioning

The patient positioning in a cephalostat is very important to acquire the correct cephalometric images. The operator should control the patient's head movement and fix the head to the ideal position in a cephalostat to minimise the errors related with the patient positioning.

1.4 Clinical Research Application of Cephalometry

Cephalometrics, the measurement of the head, has been widely used as a tool for studying craniofacial development since long before the emergence of orthodontics, and it has without doubt been the most frequently applied quantitative technique within orthodontic research. It has been used to compare, differentiate, and describe: (1) individual subjects and groups of subjects, (2) normal and anomalous subjects, (3) untreated and treated subjects, (4) homogenous and mixed populations, and (5) status at single time points and patterns of change through time.

1.4.1 Investigations among Untreated Subjects

1.4.1.1 Classification of Skeletal and Dental Relationships

Many classifications of morphology have been based on cephalometric analysis of untreated individuals by means of single time point images. Two preconditions must, however, be satisfied: (1) the presence of well-defined parameters according to which the types are defined, and (2) the availability of normative standards to which the values of the individuals can be compared. A large range of variables has been used to classify the craniofacial skeleton for various purposes.

1.4.1.2 Identification of Similarities and Differences in Dentoskeletal Relationships

Similarities and difference between members of different ethnic samples or between other groups have been identified on cephalograms. Even within the field of physical anthropology, cephalometrics has largely replaced classical anthropometric measurement methods, and studies of different ethnic groups and of age-related changes have provided a valuable basis for better understanding of craniofacial skeletal morphology (Brown, 1967). Anthropological data have also been used in the study of the relationships between the influences of genetic and environmental factors (Konigsberg, 1990).

1.4.2 Advantages and Limitations of Cephalometry in Research Applications

Cephalometry, in common with other diagnostic and descriptive modalities, has both advantages and limitations, some of which are related to the cephalometric analysis. The advantages and disadvantages of cephalometry are interpenetrating.

1.4.2.1 Advantages of Cephalometry

Cephalometry has been, and remains to a very large degree, the only available method that permits the investigation of the spatial relationships between cranial structures and between dental and surface structures (Graber, 1966). Study casts give more complete information on dental structures and facial photographs yield more complete information on surface features, but only cephalometric images yield accurate information on the spatial relationships between surface structures and deep structures. Compared to other available methods, for example computed tomography, magnetic resonance imaging and ultrasound imaging, cephalometrics is relatively non-invasive and non-destructive, thus producing a relatively high information yield at relatively low physiologic cost. Cephalometrics has also rendered serial assessments of growth possible and has permitted investigators to monitor the ongoing processes of treatment and growth *in vivo*. Future cephalometric research will be much increased in power and efficiency if different subsets of co-ordinate data can be acquired sequentially from the same sets of cephalograms by different investigators. Furthermore, since cephalograms are essentially two dimensional, they are relatively easy to store, reproduce and transport.

1.4.2.2 Limitations of Cephalometry

The limitations of cephalometry derive essentially from the fact that most of the advantages noted above are relative rather than absolute. The most important limitation is the fact that, although the information yield of cephalograms can be very high compared to their physiologic cost, the physiologic costs in the form of radiation exposure are real and must be fully taken into account each time a cephalogram is generated. Therefore, in contemporary use it is considered unacceptable to generate cephalograms unless they are diagnostically and therapeutically desirable in the interests of the particular patient being examined. Issacson and Thom (2001) noted that radiographic exposure was an invasive procedure and it was appropriate to seek a sensible risk/benefit balance in their use for orthodontic purposes. They also stated that radiographs yielded the greatest amount of information if they were: accurately positioned and exposed with modern equipment which has been regularly maintained, taken using the highest speed films and screens commensurate with clinical requirements, and processed carefully using chemicals that are in an appropriate condition and equipment that has been maintained regularly: in this way the best quality image may be obtained with the minimum exposure to the patient. A further complication is the inherent ambiguity in locating anatomical landmarks and surfaces on radiographic images, since the images lack hard edges, shadows, and well-defined outlines. While cephalograms themselves are two dimensional, the structures being examined are three dimensional. This contradiction leads to differential projective displacement of anatomical structures lying at different planes within the head. In the absence of information about the third dimension, it is physically impossible to locate the positions of structures accurately in two dimensions.

1.5 Computerised Cephalometric Systems

Nowadays, orthodontic offices use computers for many purposes, including appointments, recalls, appointment cards, patient tracking, correspondence, insurance filing and billing, accounting, cephalometrics, model analysis, diagnostic video imaging, treatment records, daily work sheets, inventory, supply orders, form generation, laboratory sequencing, and database of information for surveys concerning the performance of the office (Keim *et al.*, 1992). In addition, to these functions, academic orthodontic institutions use computers for research data collection and elaboration, teaching purposes and audiovisual material preparation (Pedersen *et al.*, 1988). Computerised cephalometric systems are used in orthodontics for diagnostic, prognostic, and treatment evaluation, and their popularity has increased steadily since their introduction to the market in the 1970s. It has been suggested that in North America about 10-15% of orthodontists now use computers for diagnosis, and it is expected to be a growth rate of 10% a year in this market (Keim *et al.*, 1992).

1.5.1 Advantages of Computerised Cephalometry

Before computerised cephalometry was employed, all angular and linear measurements were calculated manually after tracing the bone and soft tissues and identifying the landmarks related to the specific analysis used (Broadbent, 1931; Hofrath, 1931; Downs, 1952). The manual technique is time consuming, whereas computerised cephalometry is very fast (Jacobson, 1990; Liu and Gravely, 1991; Davis and Mackay, 1991). It can be performed in 10% of the time of a normal manual registration (Harzer *et al.*, 1989) because it is only necessary to digitise the radiological points directly on the cephalograms or the tracing paper, and the calculations are then done within seconds (Kess, 1989). This process removes human error except for errors of landmark identification (Isaacson *et al.*, 1991). In addition to the speed advantage, computerised cephalometry facilitates the use of double digitisation of the landmarks and thus significantly increases the reliability of the analysis (Baumrind and Franz, 1971b; Eriksen and Bjorn-Jorgensen, 1988). Although clinicians tend to think that double digitisation is of importance only to research applications, it should be remembered that this procedure significantly decreases errors of the cephalometric analysis during the planning of an individual patient's diagnosis and treatment. In addition to the great advantages of computerised cephalometric research applications, there are several other benefits of this method. These include: (1) easy storage and retrieval of cephalometric values and tracings, (2) integration of the cephalometric registrations within an office-management computerised system, and (3) combination of the cephalometric data with patients' files, photographs, and dental casts (Isaacson *et al.*, 1991).

1.5.2 Technical Principles

Computerised cephalometrics can be divided into two components - data acquisition and data management. Data acquisition is achieved by various means, including ionising radiation, magnets, sound, and light (Jacobson, 1990; Isaacson *et al.*, 1991). With regard to the ionising radiation modality, the commonest way of creating the x and y co-ordinates of the points is by means of a digitiser. Several papers have shown that the use of a digitiser *per se* does not improve the reproducibility of the readings when compared to measurements obtained by manual tracing. This related to the fact that most of the errors take place during the procedure of landmark identification and not during the procedure of tracing (Baumrind and Miller, 1980; Richardson, 1981; Liu and Gravely, 1991). However, there is no agreement concerning the method that is characterised by optimal reproducibility when direct digitisation, digitisation of tracings, and direct manual measurement are compared (Downs, 1952; Richardson, 1981; Houston, 1982; Oliver, 1991). The latter author has shown that direct manual measurements are superior to direct digitisation by a fivefold comparison of manual tracings with digitisation. This way of comparison has no clinical relevance, since the superiority of digitisation is achieved through time-saving by permitting double digitisation in comparison to single direct manual measurement (Oliver, 1991). The recent development of computerised digital radiography, in which the X-ray beam attenuation is recorded directly and converted to a digital image, has facilitated the direct use of a mouse on the screen (Isaacson, 1991). Before this, lateral and frontal cephalograms were digitised using a video or an image-capture expansion board attached to the computer. However, this method has shown limitations in reproducibility, mainly owing to poor resolution problems (Oliver, 1991; Ruppenthal *et al.*, 1991; Macri and Wenzel, 1993). The use of video imaging can be used in combination with other imaging modalities. It is used for profile hard and soft tissue analysis and in combination with other modalities such as sonic and conventional radiography. Video imaging is of special interest because it enables inclusion and integration with clinical photographs and dental casts (Jacobson, 1990).

1.5.3 How to Choose a Computerised Cephalometric System

An ideal system should be highly reproducible and require a minimum of time and effort to perform (Liu and Gravely, 1991). Baumrind and Miller (1980) drew up a list of requirements that should be considered when buying a computerised cephalometric system. They include the following:

1. The system should function in a language understood by the user.
2. The system should be easily understood.

3. The system should be easy to perform.
4. The system's data should be easily available for other programs, so that it is possible to change to a new system without the need to enter all patients again.
5. It should be possible to run the system on normal, IBM-compatible PCs.
6. The system should transform all digitised points into x and y co-ordinates, and all patients' co-ordinates and parameters should be stored in files.
7. The system should have all the functions needed to process all cephalometric analyses; it is important that the user can define his own analysis.
8. The system should posses the capability for double digitisation.
9. It should be easy to correct and add new points to the system without the need to digitise the whole picture again.
10. It should be possible to describe changes from one picture to another in both the x-direction and the y-direction.
11. The system should have a graphic demonstration of the patient's structures.

These criteria concern only the computerised cephalometric program. The user should also consider the office management systems and eventual need to connect the computerised cephalometric program with an office management system.

CHAPTER 2

X-ray Image Manipulation

2.1 A Computer-aided Image Manipulation Method for Cephalograms

The effectiveness of computer-aided x-ray image manipulation has already been established in general dentistry (Wenzel, 1993; Versteeg and van der Stelt, 1995; Yoon, 2000), especially in the field of caries detection (Pitts and Renson, 1986; Wenzel *et al.*, 1993; Shrout *et al.*, 1996), endodontic diagnosis (Mol and van der Stelt, 1989; Tyndall *et al.*, 1990; Mol and van der Stelt, 1992), and periodontal evaluation (Webber *et al.*, 1982; Grondahl *et al.*, 1983; Ohki *et al.*, 1988;). Pitts and Renson (1986) reported that a computer-aided image analysis method of estimating the depth of penetration of radiolucencies in enamel produced consistently better results than those achieved by unaided visual assessments. Webber *et al.* (1982) noted that an image subtraction of two serially-obtained radiographs increased the detectability of small temporal changes in surrounding bone. In orthodontics, x-ray images, especially cephalograms, are also very important since cephalometric analysis has been the most common tool in daily orthodontic practice and research (Tweed, 1946; Downs, 1948, 1952, 1956; Steiner, 1953, 1959, 1960; Ricketts, 1960; McNamara, 1984), and some investigators have attempted computer-aided image enhancement of cephalograms (Oka and Trussell, 1978; Jackson *et al.*, 1985; Eppley and Sadove, 1991; Macri and Wenzel, 1993; Forsyth and Davis, 1996; Forsyth *et al.*, 1996).

Oka and Trussell (1978) noted that landmarks in the cranium were more clearly defined by digital image enhancement, and Forsyth *et al.* (1996) reported that digital imaging had potential advantages over traditional cephalometry: the reduction in radiation exposure to the patient, image storage, image manipulation, image transmission, and the possibility of automated cephalometric analysis. Eppley and Sadove (1991) reported that digital enhancement was consistently superior at delineating soft tissue relationships. On the other hand, the lower reliability of landmark location using low-cost digital equipment was also reported (Macri and Wenzel, 1993).

Many orthodontists today are using computer-aided cephalometric analysis software, but cephalometric images are sometimes manipulated by orthodontists based on experience rather than on logical methods. Standardized methods are therefore necessary to allow uniform manipulation and analysis of cephalograms by orthodontists. The purpose of this study was to describe and evaluate a logical method of computer-aided x-ray image manipulation.

2.1.1 Material and Methods

2.1.1.1 X-ray Image Model

An image model of a cephalogram with 8-bit, 256 greyscale colours was prepared (Fig. 2.1a). The image had black, grey and white colour areas, and each area was divided into two slightly different colour sub-areas; the difference between adjoining areas were 11 or 12 levels at 8-bit, 256 greyscale colours (Table 2.1).

2.1.1.2 Manipulation Method

A logical image manipulation was applied in the following manner using an image manipulation software (the Gimp 1.0.4, the Gimp community, http://www.gimp.org) working on Linux.

1. The original image was duplicated and inverted after duplication.
2. The inverted image was blurred.
3. The original image was combined with the blurred image.
4. An intentionally dull contrast image was produced.
5. Colour level adjustment was applied for the dull contrast image.
6. A manipulated image appeared.

The above manipulation method is also shown in Fig. 2.2. The manipulated image was compared with the original image. An image with level adjustment only (Fig. 2.1b) was prepared as a control for the effect of the present manipulation method. The 8-bit, greyscale colour levels of all the images were measured by the Density Profile Tool in the NIH Image 1.6.2 (National Institutes of Health, http://rsb.info.nih.gov/nih-image).

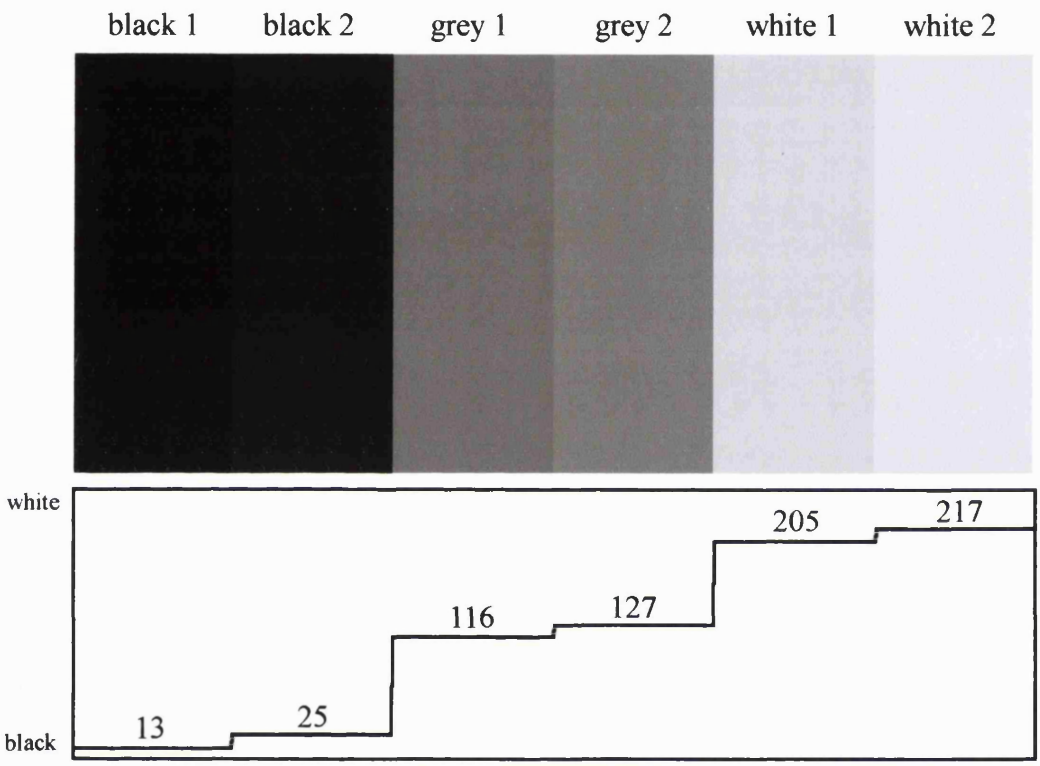

Fig. 2.1a. Colour level of the sample image at 8-bit, 256 greyscale colours.
a: original image

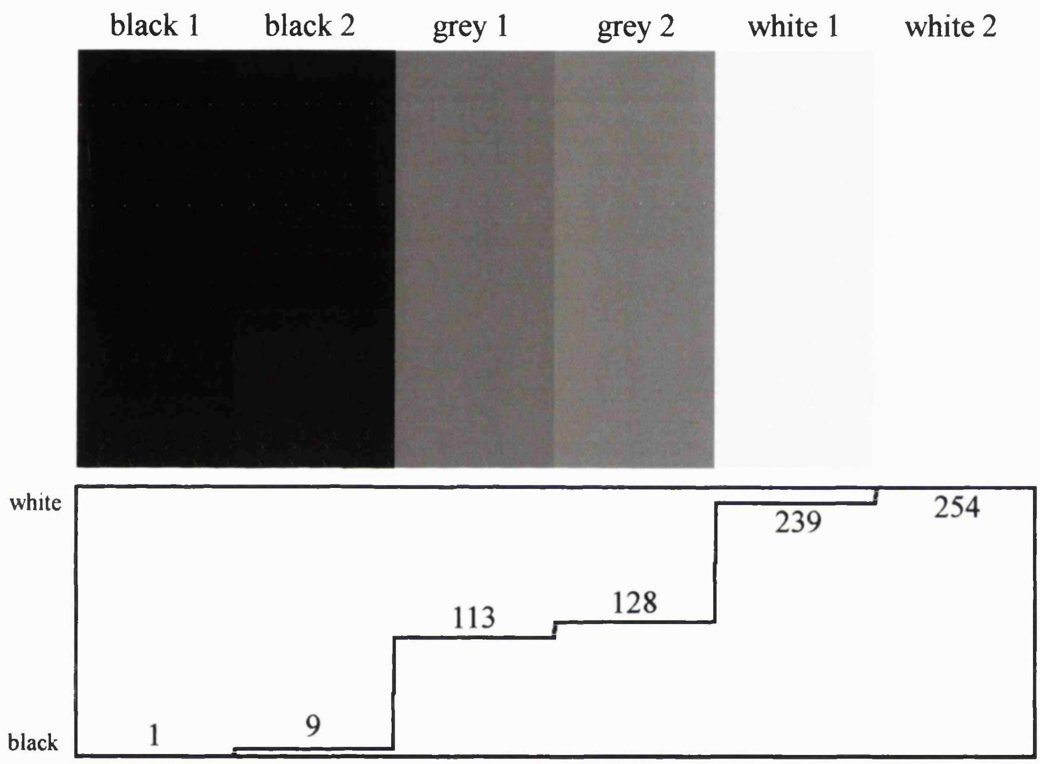

Fig. 2.1b. Colour level of the sample image at 8-bit, 256 greyscale colours.
b: manipulated image with the level adjustment only

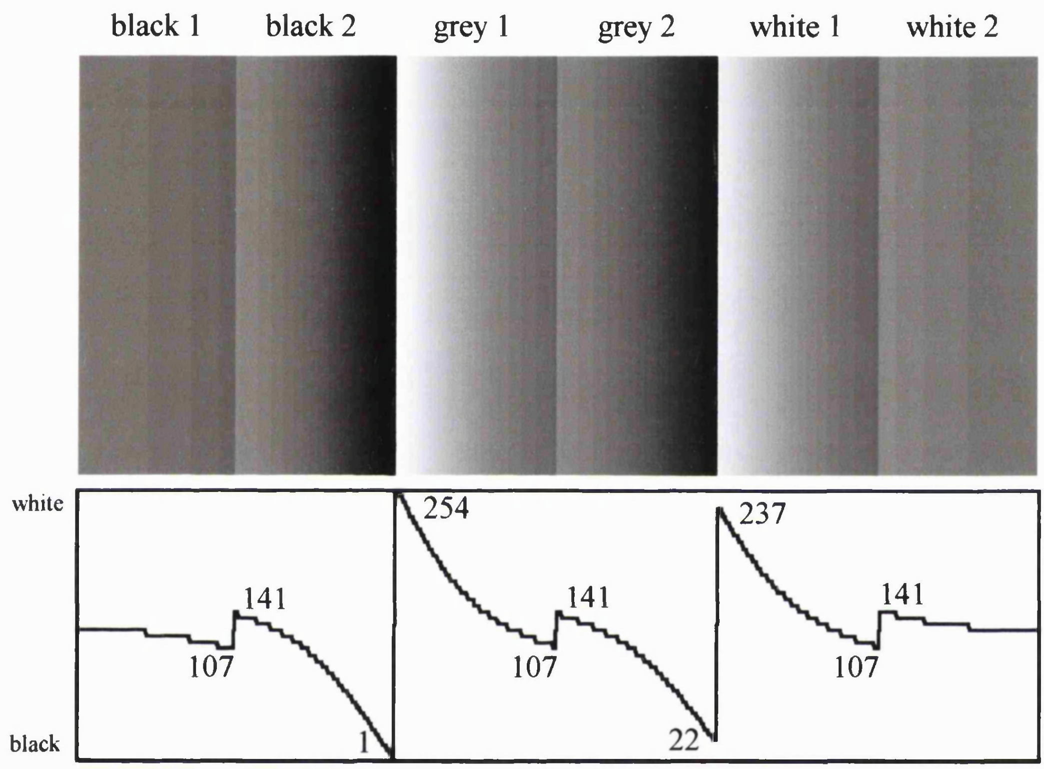

Fig. 2.1c. Colour level of the sample image at 8-bit, 256 greyscale colours.
c: manipulated image with the present method

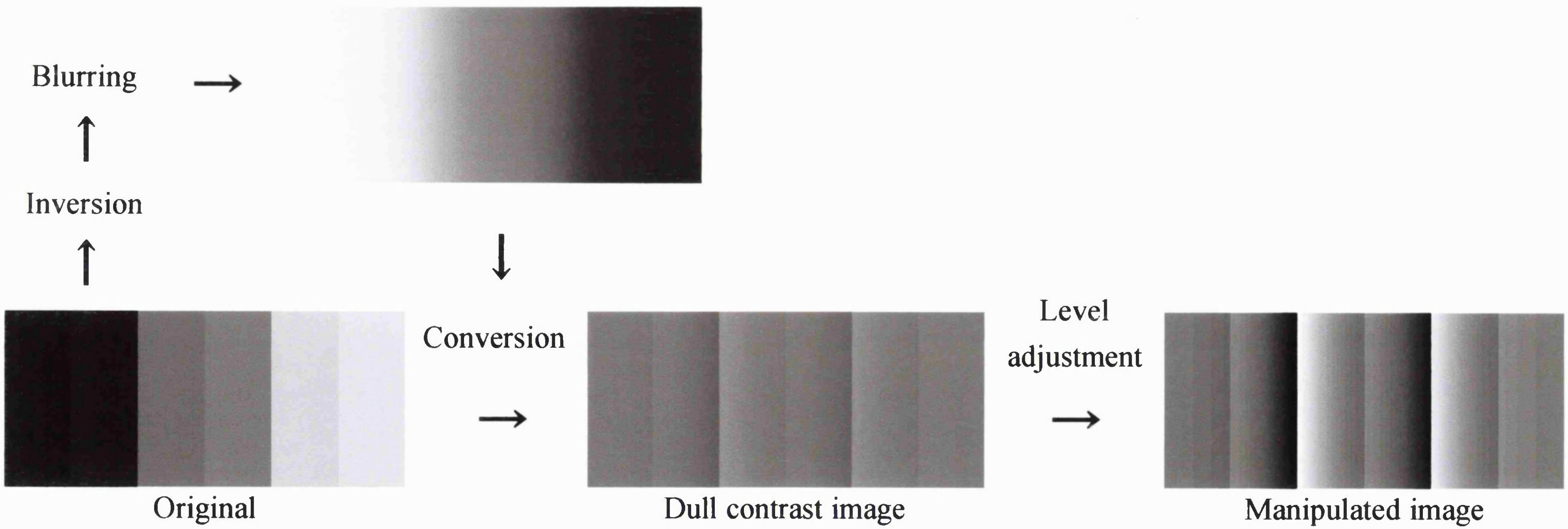

Fig. 2.2. Description of the present image manipulation method

2.1.2 Results

The manipulated image is shown in Fig. 1c, and the results of manipulation are presented in Table 1. The original image had 13-217 levels at 8-bit, 256 greyscale colours, 11-12 level differences within each black, grey and white colour, and 78-91 level differences between colours. The image only level adjustment applied had 1-254 levels, 8-15 level differences within each colour, and 104-111 level differences between colours. The manipulated image had 1-254 levels, 34 level differences within each colour, and 215-253 level differences between colours. The colour level differences were maximised by the present method.

Table 2.1. Colour level differences between adjoining areas at 8-bit, 256 greyscale colours.

	black				grey				white		
	Area 1	difference	Area 2	difference	Area 1	difference	Area 2	difference	Area 1	difference	Area 2
Original	13	12	25	91	116	11	127	78	205	12	217
Level adjustment only	1	8	9	104	113	15	128	111	239	15	254
Present method	- 107	**34**	141 1	**253**	254 107	**34**	141 22	**215**	237 107	**34**	141 -

2.1.3 Clinical Application of Cephalograms

This logical manipulation method was applied for a cephalogram (Fig. 2.3a). The original image was scanned by a flatbed scanner with transparency adaptor (Linotype-Hell JADE2, Heidelberger Druckmaschinen AG, Heidelberg, Germany) at 100 dpi with 8-bit, 256 greyscale colour. The manipulated image (Fig. 2.3b) was produced by the same manner as the greyscale image model. It had good contrast and colour balance, and facilitated the identification of the cephalometric landmarks.

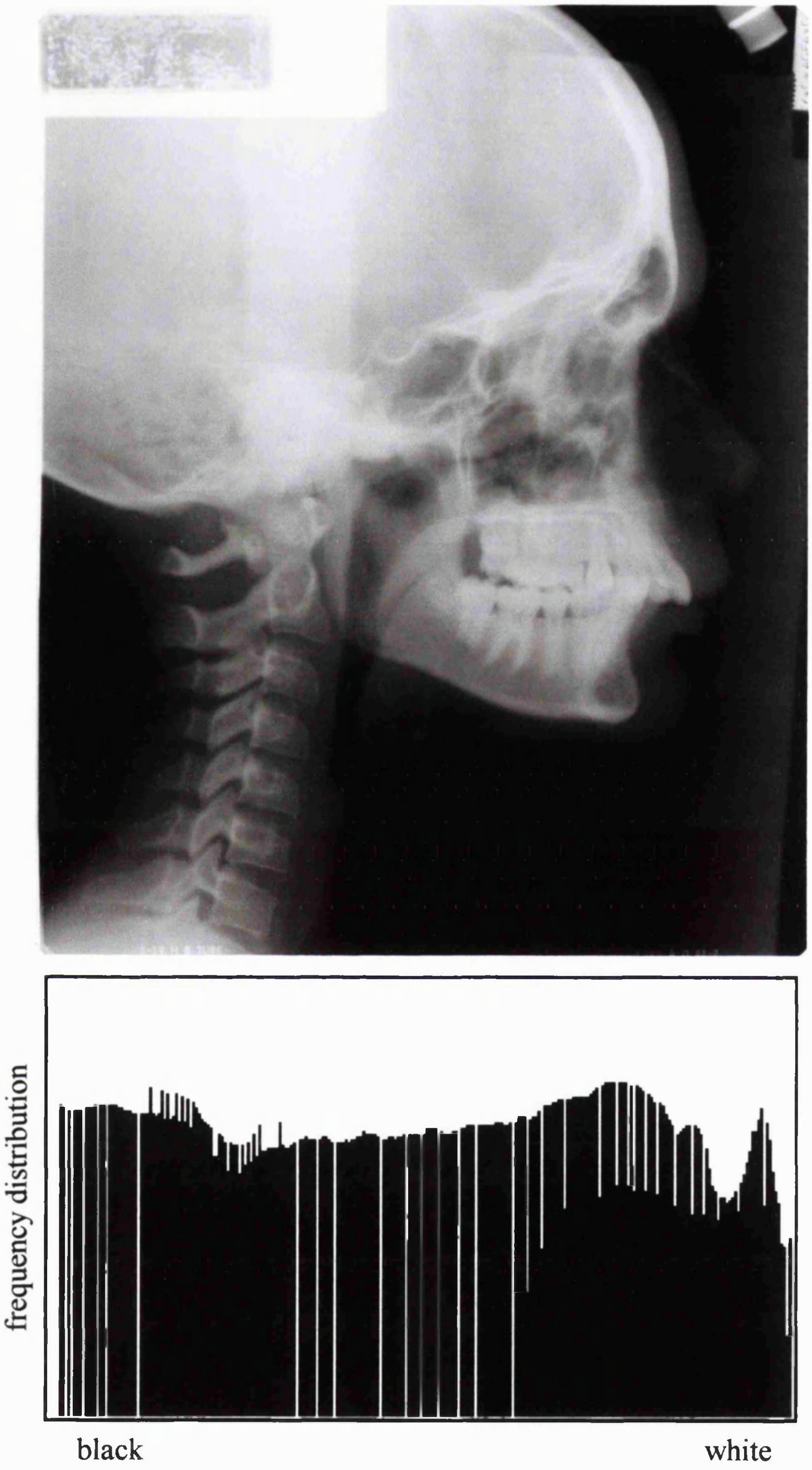

Fig. 2.3a. Colour level of the sample cephalogram at 8-bit, 256 greyscale colours.
a: original cephalogram

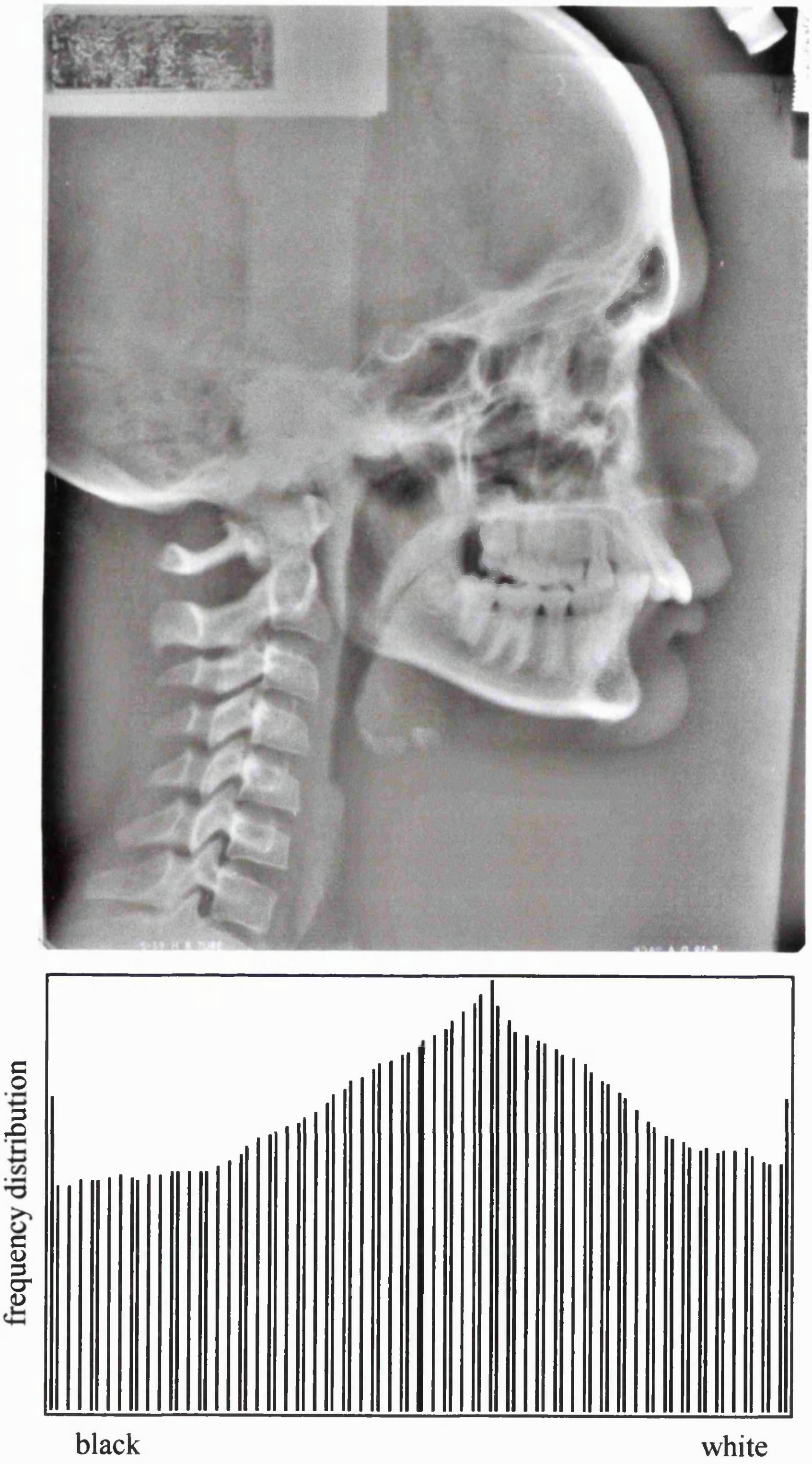

Fig. 2.3b. Colour level of the sample cephalogram at 8-bit, 256 greyscale colours.
b: manipulated cephalogram with the present method

2.1.4 Discussion

The principle of the image manipulation method should be discussed. Eight-bit greyscale images have 256 colours ranging from pure white to black. Ideally, clear cephalograms with good contrast must have a wide colour range in 8-bit, 256 greyscale colours. Therefore, the basic concept behind the image manipulation is to expand the colour range of the cephalogram to full 8-bit, 256 greyscale colours with the dark and bright grey areas being changed into the real black and white areas. However, if the original cephalometric image was simply changed into 8-bit full range, the image would have very high contrast, and some target margins could have reduced contrasts (Fig. 2.1b). As such the image would not be suitable for analysis. Therefore, to avoid this problem, the original image had to be modified before the colour level adjustment. The brighter areas of the cephalometric image were manipulated to be slightly darker, while the darker areas maintained their dark colour. As a result of this modification, the image had a very dull contrast in order to provide an image with a narrow colour range which could have more equal colour steps from black to white after expanding the colour range (Fig. 2.4). The diagram beneath Fig. 2.3b shows the colour levels of the cephalogram after expanding the colour range which should be compared with diagram beneath Fig.2.3a.

This technique allows a clearer differentiation of different colours between areas of similar colours and facilitates identification of the margins of various craniofacial structures in the cephalogram. However, the present manipulation method was not effective for digital images obtained from very low quality x-ray films such as reported in previous studies (Macri and Wenzel, 1993; Forsyth *et al.*, 1996); good quality original cephaograms were needed for analysis prior to using the present manipulation technique.

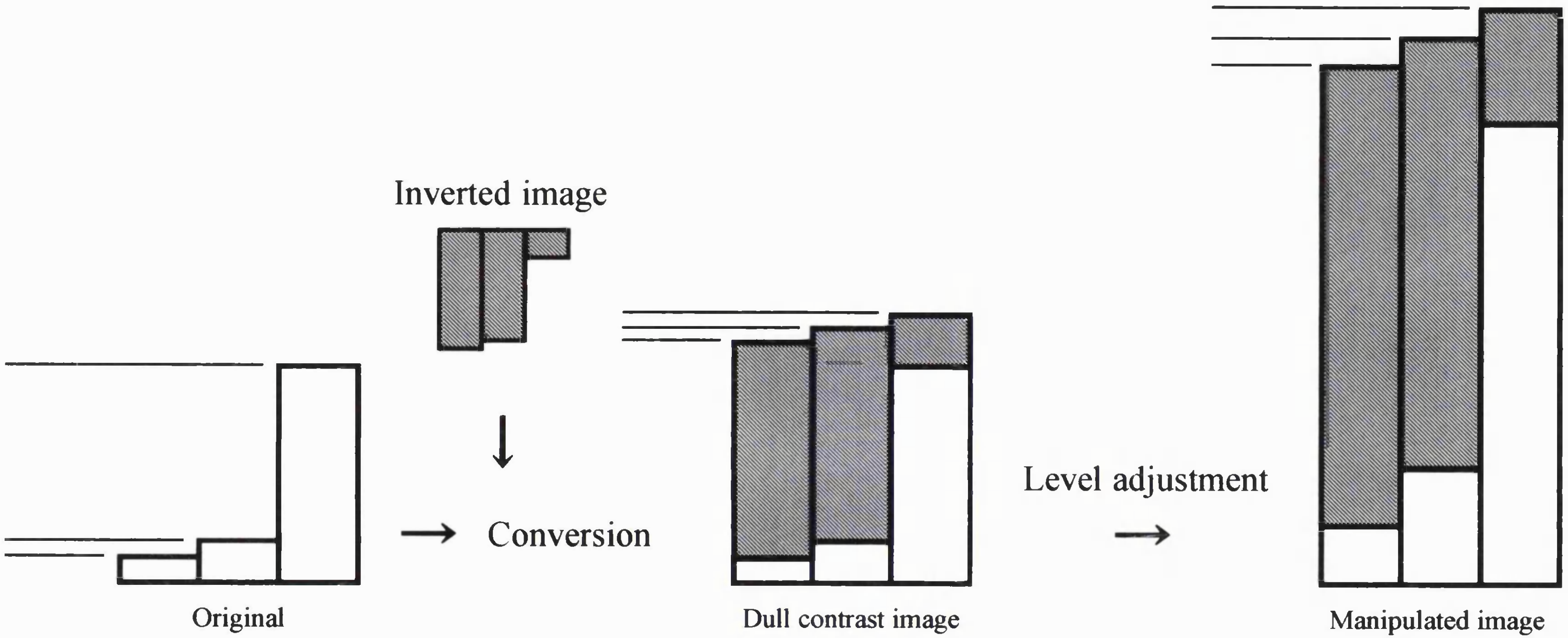

Fig. 2.4. Concept of the present image manipulation method.

2.1.5 Conclusions

The cephalometric image manipulation method can be summarized as follows: (1) X-ray image manipulation must be logical (2) An intentionally dull contrast image was important for manipulation (3) Clear images have wide colour range so that the colour levels of the manipulated cephalometric image should be expandable into full range of 8-bit, 256 greyscale colours.

The manipulated images had maximised the colour level differences at the target margins compared with the original and high-contrast images. The appropriate contrast and sharpened marginline facilitated to the identification of cephalometric landmarks. Thus, the present x-ray image manipulation method can be helpful for orthodontists in cephalometric analyses.

In addition, the present image manipulation method was used through the followed studies for all raw maesurements.

CHAPTER 3

Class I "Normal" Occlusions

3.1 Craniofacial Differences between Japanese and Caucasians with Class I Normai Occlusions (Study 1)

Cephalometric radiographs have been one of the most important diagnostic tools for orthodontic patients. Cephalometric analyses based on Caucasian populations have been the de facto standards in the orthodontic field all over the world (Downs, 1948, 1952, 1956; Steiner, 1953, 1959, 1960; Ricketts, 1960; Mills, 1970; McNamara, 1984). Many orthodontic techniques were designed for the treatments of Caucasian patients (Tweed, 1946, 1966; Andrews, 1972, 1976; Begg and Kesling, 1977; Roth, 1987). To understand the differences between races must be very important since many countries have a multiracial society, and modifications of treatment methods may be required in each race. Although many Japanese orthodontists have preferred to use techniques based upon the Caucasian races, this is based upon the asumption that there were no racial differences in the underlying morphology and growth pattern between Japanese and Caucasians. Relatively few studies have examined the craniofacial structure between the normal Japanese and Caucasian populations (Aoki, 1972; Masaki, 1980; Nezu *et al.*, 1982; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996). Masaki (1980) examined the racial differences of cranial base morphology between Japanese and Caucasians using 51 Japanese and 48 American white adolescents with normal occlusions. He reported that Japanese subjects had a significantly shorter anterior cranial base length, a longer posterior cranial base length, and a larger anterior facial height; Japanese subjects showed a high-angle facial pattern associated with a backward rotation of the mandible. Miyajima *et al.* (1996) demonstrated the racial differences of craniofacial structure between Japanese and Caucasians using 54 Japanese and 125 European-American adults with ideal occlusions. According to their study, the Japanese sample was smaller in anteroposterior facial dimensions and proportionately larger in vertical facial dimensions; the Japanese sample indicated a more downward direction of facial development. Some comparative studies between Chinese and Caucasians have also demonstrated the racial differences in the craniofacial structure between the normal Chinese and Caucasian populations (Cotton *et al.*, 1951; Cooke and Wei, 1989; Zeng *et al.*, 1998). Zeng *et al.* (1998) examined the racial differences of craniofacial morphology between Chinese and Caucasians using 40 Chinese and 40 Swedish children with Angle's Class I occlusions. Compared to the Caucasian sample, the Chinese sample had a significantly smaller anterior cranial base and the maxilla, and larger both anterior and posterior facial heights.

The purpose of the present study was to further define the morphological characteristics of Class I normal occlusion in Japanese females and to compare these features with those of Caucasian females with a normal Class I occlusion, thereby clarifying the differences in craniofacial morphology between both races.

3.1.1 Material and Methods

3.1.1.1 Subjects

The lateral cephalometric radiographs of 26 Japanese females with normal Class I occlusions were compared with the established standard cephalometric values of Caucasian females with Class I normal occlusions (Scheideman *et al.*, 1980). The Japanese subjects selected from 150 undergraduate students at the Matsumoto Dental University, Japan were not a true selected sample but was representative of a cross-section of non-growing Japanese as X-ray taken by the dental students. All the Japanese sample were satisfied the followed criteria: (1) Angle's Class I molar relationship with little or no crowding as assessed from study casts, (2) A-N-B angle above 1° but less than 4°, (3) no previous history of any orthodontic treatment, and (4) an acceptable profile. The Japanese subjects were aged 23-27 years and were matched with the established Caucasian data.

3.1.1.2 Cephalometric Analysis

All lateral cephalometric radiographs of the Japanese Class I sample were taken using the same cephalostat system. The magnification of the cephalostats were 10.0% and 8.3% for the test and control data respectively; all linear measurements reported in this study were adjusted accordingly. The lateral cephalometric radiograph of each Japanese subject was traced by the same investigator. The selected landmarks were digitised and converted to an x-y co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Fig. 3.1). The

12 linear and 10 angular measurements were derived from the parameters used in the study by Scheideman *et al.* (1980), and these parameters were compared with those of the Class I standards.

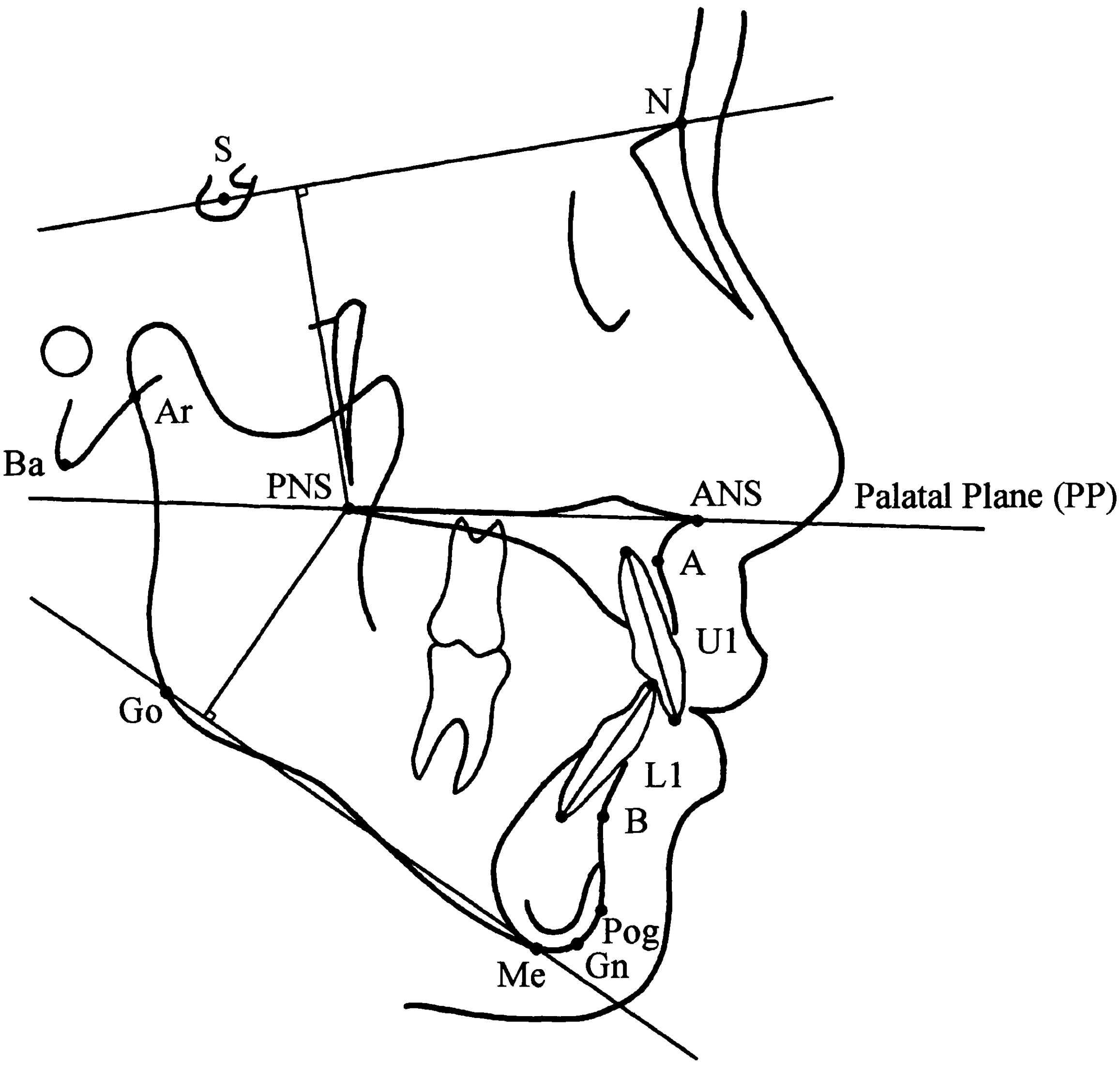

Fig. 3.1 Cephalometric landmarks recorded in Study 1.
- see section 1.2 for definition of landmarks -

3.1.1.3 Error of the Method

26 Japanese lateral cephalograms were re-traced and re-digitised 3 weeks after the initial analysis. The error of the method was examined by the coefficient of reliability, and was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 3.1.

3.1.1.4 Statistical Analysis

The means and standard deviations of the cephalometric parameters were calculated. Application of parametric tests for all cephalometric parameters was practically justified since parametric tests had the robustness for distribution (Ichihara, 1990). Equality of variance was tested between each of the groups using the F-test, and differences between groups were identified using the unpaired Student's and Welch's *t*-test; the former was applied for the parameters which had equal variances, and the later was applied for those which had unequal variances at the F-test.

3.1.2 Results

The Student's *t*-test was applied for all the cephalometric parameters since they had equal variances at the F-test. The coefficient of reliability for all cephalometric parameters satisfied the level of reliability above 0.90 (Houston, 1983). The results of comparison between cephalometric measurements of Japanese and Caucasian females with Class I normal occlusion are presented in Table 3.1.

3.1.2.1 Cranial Base Relationships

Japanese patients had a significantly shorter anterior cranial base length (S-N) and longer posterior cranial base length (S-Ba) compared with the Caucasians ($p<0.001$ and 0.05 respectively). However, the total cranial base length (N-Ba) was not significantly different between the two groups. The mean cranial base angle (the N-S-Ba angle) in the Caucasian subjects was mathematically calculated from the mean values of the other linear parameters in the cranial base relationships. Statistical tests could not apply for this parameter, but the Japanese sample had a slightly more obtuse cranial base angle compared with the Caucasian sample.

3.1.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla was evaluated by S-A, ANS-PNS, and the S-N-A angle. Only S-A was significantly more retrusive in the Japanese females compared with the Caucasians ($p<0.05$). The size of the maxilla (ANS-PNS) and S-N-A angle were not significantly different between the groups. The vertical position of the maxilla was evaluated by N-ANS, PNS to S-N, and the PP/S-N angle. The Japanese subjects had a significantly longer upper anterior facial height (N-ANS) and a significantly larger PP/S-N angle ($p<0.001$ and $p<0.01$ respectively). However, the upper posterior facial height (PNS to S-N) was not significantly different between the groups.

3.1.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by the S-N-B angle and S-Gn. There was no significant difference in either angular and linear parameters between the two groups. The vertical position of the mandible was evaluated by the S-N/Go-Gn angle. The mandibular plane angle (the S-N/Go-Gn angle) in the Japanese group was significantly larger compared with the Caucasians ($p<0.05$). The form of the mandible was examined by Ar-Go, Go-Pog, and the Ar-Go-Me angle. The Japanese females had a significantly longer mandibular ramus height compared with the Caucasians ($p<0.05$), but the mandibular body length and the gonial angle (the Ar-Go-Me angle) were not significantly different between the groups.

3.1.2.4 Intermaxillary Relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A-N-B angle. There was no significant difference between the groups and this confirmed the sample selection criteria. The vertical distance between the palatal and mandibular planes was examined by ANS-Me, PNS to Go-Me, and the PP/Go-Me angle. The linear parameters showed a significantly longer lower anterior (ANS-Me) and posterior facial height (PNS to Go-Me) in the Japanese patients ($p<0.001$), but the angular parameter did not show a significant difference between the two groups.

3.1.2.5 Dentoalveolar Relationships

The inclination of both upper and lower incisors was examined. The Japanese females had significantly more proclined upper incisors compared with the Caucasians ($p<0.01$), but the inclination of lower incisors was similar between the two groups.

Table 3.1a. Comparison of mean values between Japanese and Caucasian females with Class I normal occlusions.

			Present study Japanese Class I (N=26)			Scheideman *et al.* (1980) Caucasian Class I (N=24)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Cranial Base Relationships								
	S-N	(mm)	0.988	63.9	2.4	67.9	3.3	***
	S-Ba	(mm)	0.979	45.0	3.1	42.8	2.6	*
	N-Ba	(mm)	0.982	99.9	3.9	100.6	4.8	NS
	N-S-Ba	(°)	0.984	132.6	4.7	129.2	-	-
Maxillary Skeletal Relationships								
Antero-Posterior	S-A	(mm)	0.985	79.5	2.9	81.8	3.4	*
	S-N-A	(°)	0.986	81.5	3.0	82.6	3.6	NS
	ANS-PNS	(mm)	0.952	49.4	2.6	49.0	2.7	NS
Vertical	N-ANS	(mm)	0.956	52.8	2.1	50.0	2.7	***
	PNS to S-N	(mm)	0.973	44.4	2.3	43.8	2.5	NS
	PP/S-N	(°)	0.965	9.6	3.0	7.0	3.5	**

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***).

Table 3.1b. Comparison of mean values between Japanese and Caucasian females with Class I normal occlusions.

				Present study Japanese Class I (N=26)		Scheideman *et al.* (1980) Caucasian Class I (N=24)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Mandibular Skeletal Relationships								
Antero-Posterior	S-N-B	(°)	0.985	79.0	3.0	80.1	3.0	NS
	S-Gn	(mm)	0.997	120.6	4.7	118.7	4.5	NS
Vertical	S-N/Go-Gn	(°)	0.993	33.2	5.1	30.3	4.7	*
Mandible	Ar-Go	(mm)	0.992	46.0	3.9	43.5	4.4	*
	Go-Pog	(mm)	0.987	73.7	4.0	74.4	3.7	NS
	Ar-Go-Me	(°)	0.985	126.0	6.8	126.5	5.0	NS

Significance levels are denoted as: no significant difference(NS) and $p<0.05$(*).

Table 3.1c. Comparison of mean values between Japanese and Caucasian females with Class I normal occlusions.

			Present study Japanese Class I (N=26)			Scheideman *et al.* (1980) Caucasian Class I (N=24)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Intermaxillary Relationships								
Antero-Posterior	A-N-B	(°)	0.980	2.5	0.8	2.5	1.8	NS
Vertical	ANS-Me	(mm)	0.994	65.9	3.8	62.0	3.1	***
	PNS to Go-Me	(mm)	0.980	42.5	3.5	38.9	3.7	***
	PP/Go-Me	(°)	0.988	25.8	4.9	25.0	4.2	NS
Dentoalveolar Relationships								
	U1/S-N	(°)	0.993	106.5	6.1	101.7	5.4	**
	L1/Go-Me	(°)	0.995	94.2	8.7	95.6	6.7	NS

Significance levels are denoted as: no significant difference(NS), $p<0.01$(**), and $p<0.001$(***).

3.1.3 Discussion

In general, the majority of previous studies that have compared the craniofacial morphology between Asians and Caucasians reported that Asian populations had a shorter anterior cranial base length (Masaki, 1980; Nezu *et al.*, 1982; Cooke and Wei, 1989; Miyajima *et al.*, 1996; Zeng *et al.* 1998), and a similar result was found in the present study. The shorter anterior cranial base length could be a distinct racial difference of craniofacial morphology between Asians and Caucasians, and this difference might be based on the skeletal differences between the brachycephalic and dolichocephalic facial patterns since most Asians have the former and Caucasians have the latter (Enlow and Hans, 1996).

Compared to the Caucasian sample, an excessive vertical development was found in the Japanese sample in this study. This high-angle facial pattern in the Japanese females was produced from a longer anterior facial height associated with the backward rotated mandible. Some previous investigators have reported similar findings (Masaki, 1980; Nezu *et al.*, 1982), and therefore it would appear that the Japanese population tends to have a greater vertical development compared to Caucasians. Masaki (1980) noted that the backward rotation of the mandible and the retrusive maxilla in Japanese would be coordinated with each other, and they could maintain the antero-posterior skeletal harmony. In the present study, the Japanese sample had a similar mandible compared to the Caucasian sample in spite of a shorter anterior cranial base and mid-facial components. The Japanese sample might be required to locate the anterior limit of the mandible posteriorly in order to coordinate with the smaller cranium and the maxilla, and consequently, the backward rotation of the mandible would be found in the Japanese sample as a physiological compensation.

On the whole, a shorter anterior cranial base length and an excessive vertical development were the distinct skeletal features of the Japanese sample, but these traits were not suited to Enlow's facial growth theory (Enlow and Hans, 1996). Enlow and Hans (1996) suggested that the dolichocephalic skeletal pattern had an antero-posteriorly and vertically elongated facial pattern with a long and narrow basicranium, whilst the brachycephalic skeletal pattern was characterised by a vertically and protrusively shorter but wider midface with a rounder basicranium. According to the theory, the shorter anterior cranial base and mid-facial components in the Japanese sample are the features of the brachycephalic skeletal pattern, whilst excessive vertical development is a feature of the dolichocephalic skeletal pattern. Japanese subjects therefore had both brachycephalic and dolichocephalic skeletal features in the craniofacial structure in that there may be a brachycephalic cranium and a dolichocephalic mandible, and these components could be coordinated with physiological compensations.

3.1.4 Conclusions

The racial differences in the craniofacial structure between Japanese and Caucasian females with Class I normal occlusion were as follows: (1) Japanese females had significantly shorter anterior and longer posterior cranial base lengths, (2) Japanese females had a high-angle facial pattern with significantly longer anterior and posterior facial heights, (3) the size of the maxilla and mandible were similar in both races, and (4) Japanese females had significantly more proclined upper incisors. The shorter anterior facial height and the excessive vertical development were the key findings in this study. These skeletal features indicated the individuality of Japanese craniofacial structure which included the brachycephalic cranium and the dolichocephalic mandible. Thus, the Japanese population had a different facial pattern compared to the Caucasian population. It could be suggested that orthodontic treatment methods based on Caucasians should not be simply applied to Japanese patients without consideration of the skeletal pattern.

CHAPTER 4

Class II Malocclusion

4.1 Craniofacial Morphology of Japanese with Class II Division 1 Malocclusions (Study 2)

Analysis of craniofacial structures using lateral cephalometric radiographs has been used for the prediction of growth, as well as diagnosis and treatment planning in orthodontics (Tweed, 1946; Downs, 1952; Steiner, 1953; Ricketts, 1960; McNamara, 1984). A Class II skeletal pattern with mandibular retrusion and/or maxillary protrusion, positionally and morphologically, is a frequent dentofacial abnormality in American and European whites (Haynes, 1970; Proffit *et al.*, 1998), Chinese (Lew *et al.*, 1993), and Japanese (Susami *et al.*, 1971; Kitai *et al.*, 1990). Many studies have been attempted to clarify the morphological features of skeletal Class II malocclusion, and the majority of investigators reported the presence of a retrognathic mandible, proclined upper incisors, and neutral positioned lower incisors in Caucasian (Drelich, 1948; Renfroe, 1948; Henry, 1957; Harris *et al.*, 1972; Hitchcock, 1973; McNamara, 1981), Chinese (Lau and Hagg, 1999), and Japanese Class II patients (Miura *et al.*, 1958; Kuwahara, 1968; Iwasawa *et al.*, 1969, 1980). However, the anteroposterior position of the maxilla and the size of the mandible in Class II patients have been variously reported. In addition, the skeletal Class II pattern is affected not only horizontally but also vertically (Adams and Kerr, 1981), aided by the morphology of the cranial base (Bacon *et al.*, 1992). Thus, the skeletal and dental morphologies of the Class

II malocclusion have not been fully examined.

The aims of the present study were to further define the morphology of Japanese skeletal Class II malocclusion and to compare these features with those of normal Japanese Class I data.

4.1.1 Material and Methods

4.1.1.1 Subjects

190 lateral cephalometric radiographs of Japanese girls with Class II division 1 malocclusion and who had no history of any orthodontic treatment were examined. All the Japanese sample was selected at ramdom from the patient database at a private orthodontic office in Himeji, Japan. All of the Class II patients had no missing teeth, an A-N-B angle > 5°, Angle's Class II molar relationship, and an increased overjet as determined by clinical inspection. The control data was represented by the cephalometric standard values of Class I Japanese children published by the Japanese Society of Paediatric Dentistry (JSPD) in 1995. The Class II sample was divided into three groups based on dental age: (1) Middle mixed dentition with complete eruption of the upper and lower incisors, (2) Late mixed dentition with partial eruption of the permanent buccal segment teeth, and (3) Early permanent dentition with partial eruption of the second molars. The mean age of each

Table 4.1. Distribution of Class II division 1 and class I Japanese females.

Present study Class II div.1 Japanese (females)						Japanese Society of Pediatric Dentistry (1995) Class I Japanese (females)					
Group 1 N=76		Group 2 N=55		Group 3 N=59		Group 1 N=24		Group 2 N=29		Group 3 N=36	
7y6m - 11y0m		9y1m - 13y6m		10y9m - 15y10m		7y7m - 11y7m		8y0m - 12y1m		10y10m - 16y10m	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
8y6m	9.9m	10y11m	9.3m	13y0m	18.9m	9y1m	11.0m	10y8m	10.8m	13y2m	15.7m

group is shown in Table 4.1 and matched those of JSPD data.

4.1.1.2 Cephalometric Analysis

All lateral cephalometric radiographs of the Class II sample were taken using the same cephalostat system, and both the test and control data had the same image magnification; all linear measurements reported in this study having a 10.0% enlargement. The lateral cephalometric radiograph of each subject was traced by the same investigator. The selected landmarks were digitised and converted to an x-y co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Fig. 4.1). In this study, points Po and Or were not used since poor reproducibility has been reported previously (Cooke and Wei, 1991). The 11 linear and 17 angular measurements represented the original parameters and those derived from the analyses of Downs (1948, 1952, 1956), Steiner (1953, 1959, 1960), Jarabak (Jarabak and Fizzell, 1972), and Iizuka (Iizuka and Ishikawa, 1957). From these, 6 linear and 14 angular measurements were compared with those of the Class I standards.

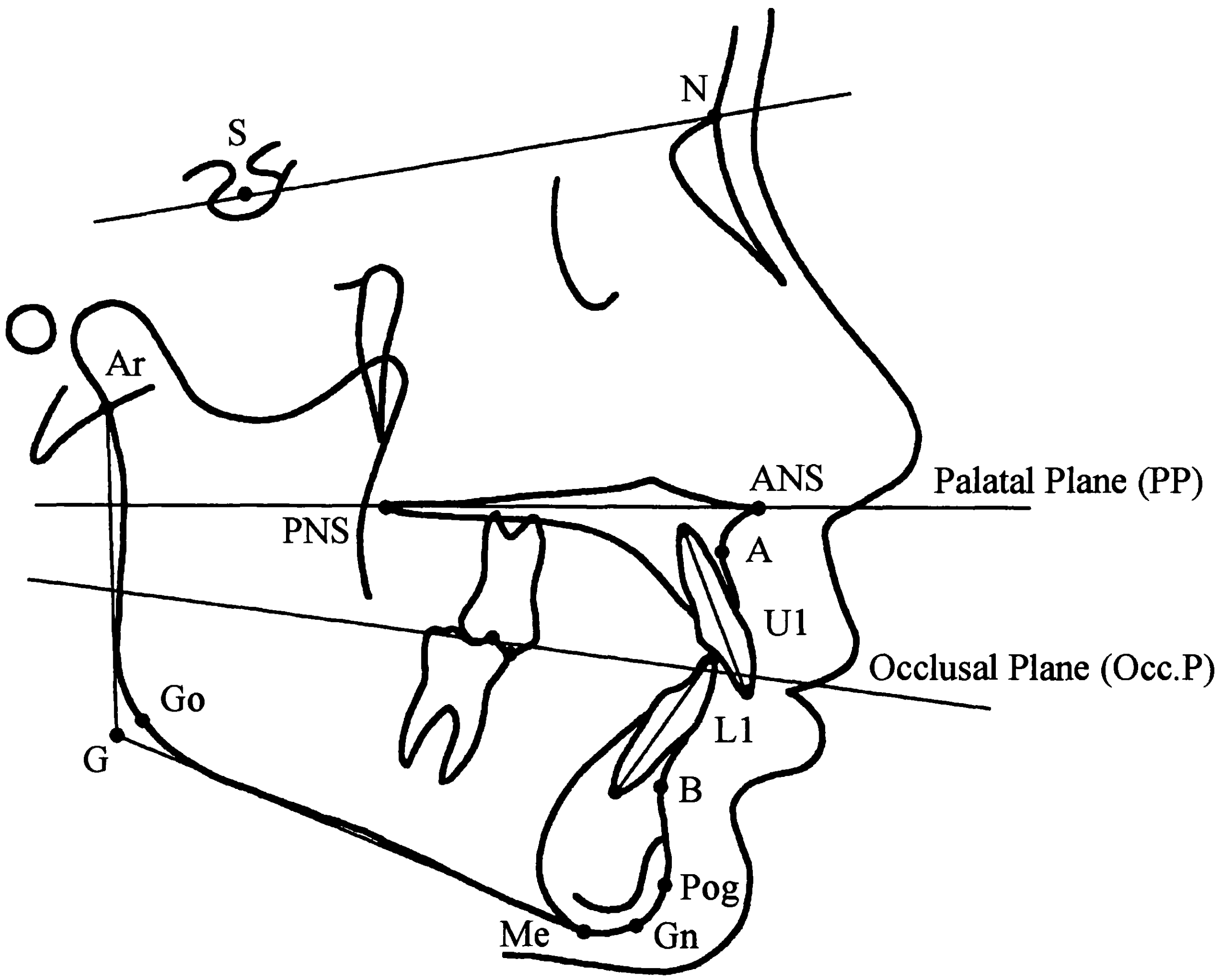

Fig. 4.1. Cephalometric landmarks recorded in Study 2.
- see section 1.2 for definition of landmarks -

4.1.1.3 Error of the Method

50 radiographs were re-traced and re-digitised two weeks after the original examination to determine the error of the method. The coefficient of reliability was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 4.2.

4.1.1.4 Statistical Analysis

Standard descriptive statistics, means and standard deviations, of age and cephalometric parameters were calculated for each group. Application of parametric tests for all cephalometric variables was practically justified since the parametric tests had the robustness for distribution (Ichihara, 1990). Equality of variance was tested between each of the groups and differences between groups identified using the unpaired Student's and Welch's *t*-test.

4.1.2 Results

The coefficient of reliability for almost all cephalometric parameters satisfied the level of reliability (>0.90). However, two results, the A-B/N-Pog and Occ.P/S-N angles, had a low coefficient of reliability (<0.90); these should be viewed with caution (Houston, 1983).

Comparison between the cephalometric measurements of the Class II division 1 Japanese girls and Class I controls are shown in Table 4.2.

4.1.2.1 Cranial Base Relationships

Although the mean anterior cranial base length (S-N) tended to be shorter in subjects with Class II division 1 malocclusions, this was significantly different only at the early permanent dentition stage of development.

4.1.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla evaluated by the S-N-A angle showed a significantly more protrusive maxilla in Class II division 1 female subjects compared with the controls (Group 2, $p<0.01$; Group 3, $p<0.01$). According to the angle between the palatal and S-N plane, the maxilla was positioned approximately in the same vertical position in both the test and control groups.

4.1.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by the S-N-B and S-N-Pog angles. The mandible in the Class II division 1 group indicated a significantly retrusive position (Group 1, $p<0.01$; Group 3, $p<0.01$), as did the chin (Group 1, $p<0.01$; Group 3, $p<0.001$). The vertical position of the mandible was evaluated by two linear parameters (N-Me, S-Me) and four angles (S-N/Ar-G, S-N/G-Me, N-Ar/S-G, and N-Pog/G-Me). The anterior facial height (N-Me) showed no significant difference between the test and control groups, but S-Me in the Class II division 1 group indicated a significantly excessive vertical development (Group 1, $p<0.01$; Group 3, $p<0.001$). Almost all angular parameters showed a significantly excessive vertical development in the Class II sample: S-N/G-Me angle (Group 2, $p<0.05$; Group 3, $p<0.001$), N-Ar/S-Gn angle (Group 1, $p<0.01$; Group 2, $p<0.01$; Group 3, $p<0.001$), and N-Pog/G-Me angle (Group 2, $p<0.05$; Group 3, $p<0.05$). In contrast, the test and control subjects had a similar S-N/Ar-G angle. The mean length of the mandibular ramus (Ar-G) was significantly shorter in the Class II division 1 sample (Group 1, $p<0.001$; Group 2, $p<0.05$; Group 3, $p<0.001$), but the mandibular body length (Go-Me) was not significantly different from the controls, except for Group 3. Subjects with Class II malocclusion also had a similar gonial angle (the Ar-G-Me angle), except for Group 1.

4.1.2.4 Intermaxillary Relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A-N-B angle and the A-B/N-Pog angle. All were significantly larger in the Class II subjects compared with the controls (Group 1, $p<0.001$; Group 2, $p<0.001$; Group 3, $p<0.001$).

4.1.2.5 Dentoalveolar Relationships

These were similar in the Class II division 1 and Class I groups except at the early permanent dentition stage of development where the lower incisors were slightly more proclined ($p<0.05$). Otherwise, the inclination of both upper and lower incisors and the occlusal plane inclination were similar in both groups.

Table 4.2a. Comparison of mean values between Class II division 1 and Class I Japanese females.

				Present study						JSPD (1995)					
				Class II division 1						Class I					
			coefficient of reliability	Group 1 (N=76)		Group 2 (N=55)		Group 3 (N=59)		Group 1 (N=24)		Group 2 (N=29)		Group 3 (N=36)	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cranial Base Relationships															
	S-N	(mm)	0.957	65.3	2.7	66.9	2.6	67.8***	2.3	65.8	2.7	67.8	3.1	69.6***	2.6
	S-Ar	(mm)	0.974	32.7	2.7	34.7	2.8	35.9	2.8	-	-	-	-	-	-
	N-S-Ar	(°)	0.978	127.3	4.4	127.2	4.4	127.2	4.7	-	-	-	-	-	-
Maxillary Skeletal Relationships															
Antero-Posterior	Ar-A	(mm)	0.991	82.2	3.3	85.0	3.9	86.8	4.0	-	-	-	-	-	-
	S-N-A	(°)	0.942	81.5	3.2	81.8**	2.9	82.0**	3.3	80.2	3.2	79.7**	3.0	80.1**	2.5
Vertical	N-ANS	(mm)	0.950	50.5	3.0	53.2	2.9	55.9	3.0	-	-	-	-	-	-
	PP/S-N	(°)	0.903	9.3	3.0	8.8	2.9	9.9	3.0	9.1	2.7	9.6	2.7	10.1	3.1

Levels of significance: $p<0.01$(**) and $p<0.001$(***).

Table 4.2b. Comparison of mean values between Class II division 1 and Class I Japanese females.

			Present study							JSPD (1995)					
			Class II division 1							Class I					
			coefficient of	Group 1 (N=76)		Group 2 (N=55)		Group 3 (N=59)		Group 1 (N=24)		Group 2 (N=29)		Group 3 (N=36)	
			reliability	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mandibular Skeletal Relationships															
Antero-Posterior	S-N-B	(°)	0.953	74.2**	2.9	75.5	3.0	75.7**	3.3	76.3**	2.9	76.3	3.1	77.6**	2.2
	S-N-Pog	(°)	0.965	73.6**	2.9	74.9	3.0	74.9***	3.3	75.4**	2.7	75.6	2.8	77.4***	2.7
Vertical	N-Me	(mm)	0.990	112.1	4.4	118.5	5.9	123.7	6.9	113.1	5.0	116.8	4.6	122.8	6.2
	S-Me	(mm)	0.995	108.2**	4.1	115.5	5.2	120.3*	6.3	111.0**	5.2	115.4	4.4	123.2*	5.6
	S-N/Ar-G	(°)	0.922	93.1	4.6	93.9	4.9	94.4	5.7	94.1	3.8	93.5	3.9	92.7	4.4
	S-N/G-Me	(°)	0.986	39.9	4.8	39.6*	5.2	40.4***	6.3	37.8	4.5	36.9*	4.7	36.1***	4.6
	S-Ar-Go	(°)	0.957	143.5	5.3	144.2	5.5	144.7	6.1	-	-	-	-	-	-
	N-Ar/S-Gn	(°)	0.980	90.5**	2.7	90.9**	3.2	92.0***	3.7	88.7**	3.5	88.6**	2.9	88.0***	2.2
	N-Pog/G-Me	(°)	0.987	66.5	3.5	65.5*	3.8	64.7*	5.2	66.8	4.1	67.5*	4.6	66.6*	3.7
Mandible	Ar-G	(mm)	0.979	39.2***	2.7	41.7*	4.0	43.9***	4.3	42.0***	2.9	43.9*	3.6	47.0***	3.3
	Go-Pog	(mm)	0.978	68.1	3.9	72.3	4.2	74.2	4.1	-	-	-	-	-	-
	Go-Me	(mm)	0.969	62.1	3.9	66.6	4.1	68.4***	3.8	63.9	4.2	67.0	2.6	72.4***	4.4
	Ar-Pog	(mm)	0.996	95.0	3.6	100.6	4.6	104.3	5.4	-	-	-	-	-	-
	Ar-G-Me	(°)	0.983	126.8**	6.4	125.7	5.9	126.0	7.9	123.7**	6.6	123.4	5.4	123.4	5.9

Levels of significance: $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***). red colour: tested by Welch's *t*-test

Table 4.2c. Comparison of mean values between Class II division 1 and Class I Japanese females.

			Present study							JSPD (1995)					
			Class II division 1							Class I					
			coefficient of	Group 1 (N=76)		Group 2 (N=55)		Group 3 (N=59)		Group 1 (N=24)		Group 2 (N=29)		Group 3 (N=36)	
			reliability	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Intermaxillary Relationships															
Antero-Posterior	A-N-B	(°)	0.924	7.3***	1.4	6.3***	1.0	6.3***	1.2	3.8***	1.5	3.3***	1.3	2.6***	1.7
	A-B/N-Pog	(°)	0.881	9.7***	2.0	8.4***	1.7	8.4***	1.8	5.2***	2.3	5.0***	2.9	4.1***	2.6
Vertical	ANS-Me	(mm)	0.989	64.9	3.7	68.2	4.7	70.9	5.6	-	-	-	-	-	-
	PP/G-Me	(°)	0.989	30.5	5.1	30.8	5.3	30.3	5.9	-	-	-	-	-	-
Dentoalveolar Relationships															
	U1/S-N	(°)	0.982	104.7	6.3	106.8	6.3	108.2	6.3	104.9	5.0	105.5	7.0	106.0	4.7
	L1/G-Me	(°)	0.972	97.8	5.2	97.8	5.4	99.3*	7.5	97.6	6.2	99.1	5.1	96.4*	5.1
	U1/L1	(°)	0.990	117.6	8.1	115.8	8.5	112.1***	9.1	119.7	6.9	118.5	9.9	121.5***	6.9
	Occ.P/S-N	(°)	0.847	22.4	3.4	20.5	3.9	20.3	3.9	22.8	2.9	21.3	3.1	19.8	3.3

Levels of significance: p<0.05(*) and p<0.001(***).

red colour: tested by Welch's *t*-test

4.1.3 Discussion

In a comparison study of this nature, ideally the study groups could be perfectly matched not only for gender, but also for sample size and age. However, standard Japanese cephalometric values noted according to chronological age are not available. Some linear parameters in this study might have wide ranges because of such groupings based on dental age; skeletal development would not perfectly correlated with dental age. The unpaired Student's *t*-test applied for this study might not be ideally suitable. The D'Agostino-Pearson test or Kolmogorv-Smirnov test should be applied to test for normality of distribution prior to using parametric tests. However, the unpaired Student's *t*-test was the only method available to compare the tests results with established control values since only mean values and standard deviations were shown in the JSPD study.

In this study, an anteriorly positioned maxilla was identified in Class II division 1 subjects compared to JSPD normal controls. However, it should not be simply concluded that Class II division 1 Japanese girls had a protrusive maxilla because the mean values (81.5, 81.8, 82.0) of the S-N-A angle (Groups 1, 2 and 3, respectively) were similar to the standard value measured by Steiner (1953, 1959, 1960). The Japanese standard values (80.2, 79.7, 80.1) of the S-N-A angle used in this study suggest a slightly retrusive maxilla, thus indicating a relatively protrusive maxilla in our subjects. Although our results showed a significant retrognathia of the mandible in the Class II sample according to the S-N-B angle, Rosenblum (1995) indicated that studies using sella-nasion based measurements showed mandibular retrusion or retrognathia and less maxillary protrusion in Class II subjects; indicating that the retrognathic mandible evaluated by the S-N-B and S-N-Pog angles should be viewed with caution. Our results also indicated a significantly short mandibular ramus (Ar-G) in Japanese girls with Class II division 1 malocclusion. Menezes (1974) noted that all mandibular dimensions, overall mandibular length, mandibular body length, and vertical ramus were significantly shorter in Class II division 1 subjects. Other investigators have also reported the presence of a short mandibular body length (Nelson and Higley, 1948; Craig, 1951; Henry, 1957). However, in these Caucasian studies, there was no significant difference in the mandibular ramus length between Class II and Class I. In the present study, no significant difference in the mandibular body length was detected relative to the control data. These data indicated that the short mandibular ramus is one of the distinctive features of Japanese female subjects with Class II division 1 malocclusion, and the short posterior facial height (Ar-G) in the present study is the cause of the dolichocephalic facial pattern. Moreover, the retrusive mandible could be explained by the short mandibular ramus, slightly short mandibular body and the obtuse gonial angle associated with backward rotation of the mandible. Although the Class II division 1 subjects had a mandibular backward rotation, there was no significant difference in the inclination of the occlusal plane between Class II division 1 and Class I cases. The dentoalveolar components in the Japanese subjects may play a role in maintaining a neutral occlusal plane, compensating for the steep mandibular angle.

4.1.4 Conclusions

The characteristic features of Japanese Class II division 1 malocclusion are as follows: (1) Slightly obtuse cranial base angle, (2) Relatively anteriorly positioned maxilla, (3) Significantly short mandibular ramus, (4) Retrognathic mandible, (5) Slightly obtuse gonial angle, (6) High-angle facial pattern, and (7) Relatively short posterior facial height associated with a short mandibular ramus.

Class II division 1 maxillary protrusion in Japanese girls is mainly caused by skeletal abnormalities. The obtuse gonial angle and high-angle facial pattern were key findings in the present study.

4.2 Craniofacial Growth of Untreated Japanese with Skeletal Class II Malocclusions (Study 3)

It is important for orthodontists to have a clear understanding of not only the morphological features but also the growth changes of Class II malocclusions. Although it has been difficult to acquire untreated serial records, some longitudinal studies which have examined the growth changes of Class II malocclusions during the deciduous dentition (Varrela, 1998), from the deciduous through the mixed or early permanent dentition (Baccetti *et al.*, 1997; Bishara *et al.*, 1997; Bishara, 1998), from the mixed through the permanent dentition (Ngan *et al.*, 1997a; Gesch, 2000), and during the permanent dentition (Carter, 1987; Pollard and Mamandras, 1995) have been attempted. Varrela (1998) reported that there were few skeletal differences between Class II and Class I samples in the deciduous dentition, with most Class II malocclusions at this stage being produced by dental disharmonies. Bishara *et al.* (1997) noted that the growth trends were essentially similar between Class II and normal subjects from the deciduous to the early permanent dentition, but the differences in mandibular length and position were more evident in the early stages of development than the later stages. Pollard and Mamandras (1995) reported that the total maxillary and mandibular growth of a Class II sample was found to be similar to that of a Class I sample from 16 to 20 years of age. There is still a lack of information regarding the understanding of the skeletal growth changes in untreated Class II malocclusions, especially during the late mixed dentition.

The purpose of this study was to clarify the skeletal growth changes of untreated Japanese skeletal Class II malocclusions during the mixed dentition and to compare these features to those of normal Japanese Class I data.

4.2.1 Material and Methods

4.2.1.1 Subjects

The lateral cephalometric radiographs of 12 Japanese girls with skeletal Class II malocclusions and who had no history of any orthodontic treatment were examined. All patients in the Class II sample had an A-N-B angle of greater than 5° and an Angle's Class II molar relationship. 14 Japanese girls with Class I normal occlusions supplied the control data. All the control patients had an A-N-B angle of greater than 2° but less than 4°, and an Angle's Class I molar relationship. The normal A-N-B angle for the Japanese population has been reported at 3° (Uesato *et al.*, 1978). Each subject had two sets of serial records; the first record (D1) was taken at approximately 8 years of age, and the second (D2) at 11 years of age; the mean age of each stage is shown in Table 4.3. Both Class II and Class I samples stisfied with the above criteria were selected from the patient database at a private orthodontic office in Himeji, Japan.

Table 4.3. Age distribution of skeletal class II and class I Japanese females.

Class II Japanese (females) N=12						Class I Japanese (females) N=14					
D1			D2			D1			D2		
Mean	SD	range	Mean	SD	range	Mean	SD	range	Mean	SD	range
7y10m	4.0m	7y6m-8y6m	11y0m	4.8m	10y6m-11y6m	8y0m	6.2m	7y2m-8y9m	11y3m	6.4m	10y2m-11y10m

4.2.1.2 Cephalometric analysis

All lateral cephalometric radiographs of both the Class II and Class I samples were taken using the same cephalostat system, and both the test and control data had the same image magnification; all linear measurements reported in this study having 10.0% enlargement. The lateral cephalometric radiographs of each subject were traced by the same investigator. The selected landmarks were digitised and converted to an x-y co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Fig. 4.3). In this study, points Po, Or, and the Frankfort Horizontal plane were not used since poor reproducibility has been reported previously (Adenwalla *et al.*, 1988; Cooke and Wei, 1991; Perillo *et al.*, 2000). The 13 linear and 10 angular measurements represented the original parameters and those derived from the analyses of Steiner (1953, 1959, 1960) and Jarabak (Jarabak and Fizzell, 1972).

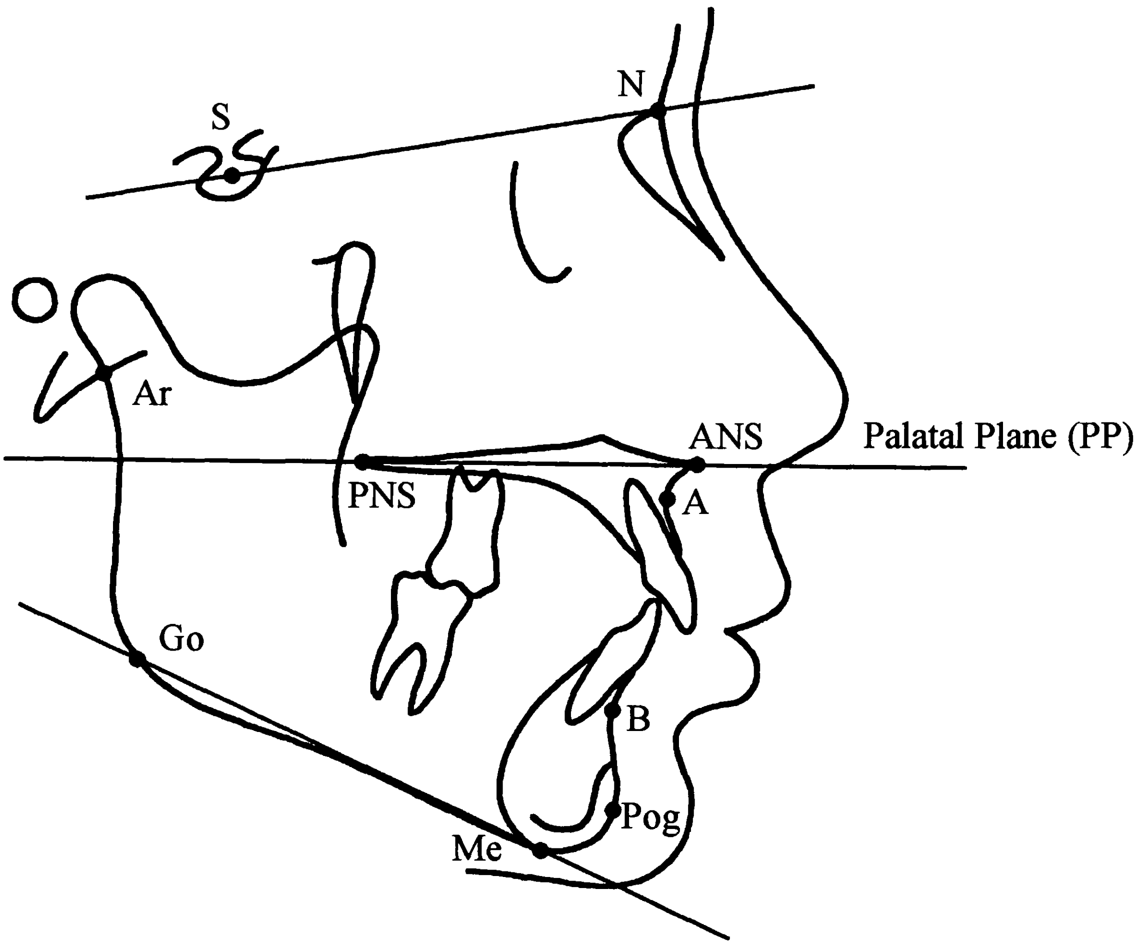

Fig. 4.2. Cephalometric landmarks recorded in Study 3.
- see section 1.2 for definition of landmarks -

4.2.1.3 Error of the Method

All 52 radiographs were re-traced and re-digitised 3 weeks later. The coefficient of reliability was calculated for each measurement to examine the error of the method. The method is shown as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 4.4.

4.2.1.4 Statistical Analysis

Means and standard deviations of all parameters were calculated. Equality of variance was tested between each of the groups which had a normal distribution as supported by the D'Agostino-Pearson test. The unpaired Student's and Welch's *t*-test were applied to identify the differences between groups; the former was applied for the parameters which had equal variances, whilst the later was applied for those which had unequal variances at the F-test. The statistical power was calculated in each parameter which had the statistical difference, and the required sample size was also examined.

4.2.2 Results

The coefficient of reliability for almost all cephalometric parameters satisfied the level of reliability (>0.90). However, some results had a low coefficient of reliability (<0.90); these should be viewed with caution (Houston, 1983). Comparison between the cephalometric measurements of Class II and Class I malocclusions are shown in Table 4.4 and Fig. 4.3-4.5, and statistical power of each significant parameters is shown in Table 4.5.

4.2.2.1 Cranial Base Relationships

There was no significant difference in the cranial base between Class II and Class I subjects; they had similar skeletal structures and growth magnitudes.

4.2.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla was evaluated by the linear measurements S-A and Ar-A, together with the S-N-A angle. The linear parameters, S-A and Ar-A, showed no significant difference between the two samples, but the angular parameter indicated a significant difference between both groups at D1 ($p<0.05$). The Class I controls had a significantly larger amount of anterior growth compared to the Class II subjects ($p<0.05$). According to the N-ANS length and the PP/S-N angle, both groups had a similar vertical position and growth changes of the maxillae.

4.2.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by the distance S-B and the

S-N-B angle. According to the S-N-B angle, the Class II sample had a significantly retrusive mandible at D2 ($p<0.05$). The anteroposterior position of the chin evaluated by S-Pog and the S-N-Pog angle also showed significant differences between the groups at D2 ($p<0.05$). The growth magnitude of the S-Pog was significantly larger in the Class I subjects ($p<0.05$). The vertical position of the mandible was evaluated by N-Me, the S-N/Go-Me angle, and the S-Ar-Go angle. None of these parameters showed any significant differences between the groups. The mean length of the mandibular ramus (Ar-Go) showed no significant difference between the groups, but the mandibular body (Go-Pog) and the total mandibular length (Ar-Pog) in the Class II sample were significantly shorter compared to the Class I sample ($p<0.05$ and $p<0.01$ respectively). The total mandibular length (Ar-Pog) in the Class I sample also had a significantly larger growth magnitude ($p<0.01$). Both groups had a similar gonial angle (the Ar-Go-Me angle), but the Class II subjects showed a significantly decreased growth of the gonial angle compared to the Class I controls ($p<0.05$).

4.2.2.4 Intermaxillary Relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A-N-B angle. Not surprisingly, it was significantly larger in the Class II subjects compared to the control ($p<0.001$) as this was one of the group selection criteria. The vertical height between the palatal and mandibular planes in the Class II sample was not significantly different compared to the Class I standards in both linear (ANS-Me) and angular (the PP/Go-Me angle) measurements, and both had similar vertical growth.

Table 4.4a. Comparison of mean values between skeletal Class II and Class I Japanese females.

			Class II (N=12)								Class I (N=14)							
			D1			D2			difference		D1			D2			difference	
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Mean	SD	coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Mean	SD
Cranial Base Relationships																		
	S-N	(mm)	0.952	65.0	1.7	0.956	67.5	2.2	2.5	1.6	0.970	64.9	2.4	0.971	67.4	2.7	2.5	1.0
	S-Ar	(mm)	0.935	32.0	2.0	0.986	35.3	2.5	3.3	1.5	0.958	32.0	2.5	0.979	35.1	2.7	3.1	1.2
	N-Ar	(mm)	0.942	87.4	2.6	0.988	92.2	3.0	4.8	2.7	0.979	87.7	3.9	0.988	92.6	4.3	4.9	1.3
	N-S-Ar	(°)	0.991	125.4	5.8	0.997	125.1	5.8	-0.3	2.3	0.968	126.1	4.6	0.988	126.4	6.3	0.3	2.5
Maxillary Skeletal Relationships																		
Antero-Posterior	S-A	(mm)	0.987	79.4	3.2	0.974	82.8	3.8	3.5*	2.3	0.988	77.2	2.8	0.975	82.9	3.4	5.7*	1.9
	Ar-A	(mm)	0.965	81.3	2.6	0.972	84.6	3.2	3.3*	2.2	0.981	79.4	3.8	0.980	84.8	4.0	5.5*	1.8
	S-N-A	(°)	0.976	82.4*	3.0	0.988	81.9	2.6	-0.5*	2.3	0.985	79.9*	2.3	0.963	81.0	2.9	1.2*	1.5
Vertical	N-ANS	(mm)	0.939	50.5	3.6	0.991	54.2	2.7	3.7	2.3	0.973	49.9	1.6	0.946	54.4	2.4	4.4	1.5
	PP/S-N	(°)	0.943	9.5	3.2	0.966	8.7	2.1	-0.9	2.2	0.955	9.9	1.9	0.874	10.0	1.8	0.1	0.8

The levels of significance are as follows: $p<0.05$(*).

Table 4.4b. Comparison of mean values between skeletal Class II and Class I Japanese females.

			Class II (N=12)								Class I (N=14)							
			D1			D2			difference		D1			D2			difference	
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Mean	SD	coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Mean	SD
Mandibular Skeletal Relationships																		
Antero-Posterior	S-B	(mm)	0.985	98.2	3.9	0.985	103.8	4.8	5.6	2.6	0.993	99.0	3.4	0.986	106.7	4.5	7.7	2.9
	S-N-B	(°)	0.963	75.2	2.5	0.988	75.5*	2.4	0.3	1.8	0.985	76.5	2.4	0.973	78.0*	3.1	1.5	1.7
	S-Pog	(mm)	0.976	108.8	4.3	0.997	115.9*	4.7	7.2*	3.2	0.970	109.8	3.2	0.992	119.8*	4.6	10.0*	3.3
	S-N-Pog	(°)	0.960	74.7	2.3	0.993	75.4*	2.5	0.7	1.7	0.984	76.1	2.3	0.972	77.7*	3.0	1.6	1.8
Vertical	N-Me	(mm)	0.989	110.4	4.4	0.997	117.9	4.7	7.5	2.9	0.993	111.0	2.8	0.970	119.6	4.4	8.6	2.6
	S-N/Go-Me	(°)	0.980	40.6	4.0	0.998	39.4	5.1	-1.3	2.3	0.984	39.7	3.0	0.976	38.8	3.4	-0.9	1.8
	S-Ar-Go	(°)	0.986	144.2	6.0	0.979	146.3	6.0	2.1	2.4	0.967	143.1	5.6	0.971	142.6	6.3	-0.5	4.1
Mandible	Ar-Go	(mm)	0.943	38.3	3.7	0.989	41.2	4.5	2.9	2.0	0.956	39.3	2.2	0.973	43.1	3.8	3.8	2.5
	Go-Pog	(mm)	0.976	67.2	3.7	0.973	71.9*	3.3	4.7	1.6	0.976	69.0	3.2	0.932	75.2*	3.5	6.2	2.8
	Ar-Pog	(mm)	0.982	94.3	3.7	0.996	99.9**	4.1	5.5**	2.5	0.989	96.5	3.4	0.997	105.3**	4.3	8.9**	3.4
	Ar-Go-Me	(°)	0.960	131.0	5.4	0.989	128.0	5.5	-3.0*	3.0	0.959	130.5	4.3	0.903	129.7	3.5	-0.7*	2.5
Intermaxillary Relationships																		
Antero-Posterior	A-N-B	(°)	0.960	7.1***	1.8	0.921	6.4***	1.2	-0.8	1.0	0.825	3.4***	0.6	0.759	3.0***	0.6	-0.4	0.6
Vertical	ANS-Me	(mm)	0.964	63.1	4.9	0.974	66.4	4.8	3.3	2.2	0.967	63.1	1.9	0.982	67.2	2.8	4.1	1.6
	PP/Go-Me	(°)	0.982	31.1	5.0	0.996	30.7	6.6	-0.4	2.2	0.973	29.8	3.1	0.957	28.8	3.6	-1.0	1.8

The levels of significance are as follows: $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***). red colour: tested by Welch's *t*-test

Table 4.5. Results of calculation for statistical power and required sample size in significant parameters.

		Class II (N=12)		Class I (N=14)				
		Mean	SD	Mean	SD	Significance level	Statistical power (%)	Required sample size (statistical power > 80%)
D1	S-N-A	82.4	3.0	79.9	2.3	0.05	64.0	18.1
	A-N-B	7.1	1.8	3.4	0.6	0.001	98.8	1.9
D2	S-N-B	75.5	2.4	78.0	3.1	0.05	61.8	19.7
	S-Pog	115.9	4.7	119.8	4.6	0.05	54.0	22.8
	S-N-Pog	75.4	2.5	77.7	3.0	0.05	58.0	21.8
	Go-Pog	71.9	3.3	75.2	3.5	0.05	67.4	17.5
	Ar-Pog	99.9	4.1	105.3	4.3	0.01	91.2	9.1
	A-N-B	6.4	1.2	3.0	0.6	0.001	80.3	1.3
Difference	S-A	3.5	2.3	5.7	1.9	0.05	75.9	14.0
	Ar-A	3.3	2.2	5.5	1.8	0.05	75.9	14.1
	S-N-A	-0.5	2.3	1.2	1.5	0.05	56.0	21.5
	S-Pog	7.2	3.2	10.0	3.3	0.05	59.9	20.4
	Ar-Pog	5.5	2.5	8.9	3.4	0.01	82.9	12.2
	Ar-Go-Me	-3.0	3.0	-0.7	2.5	0.05	54.0	14.0

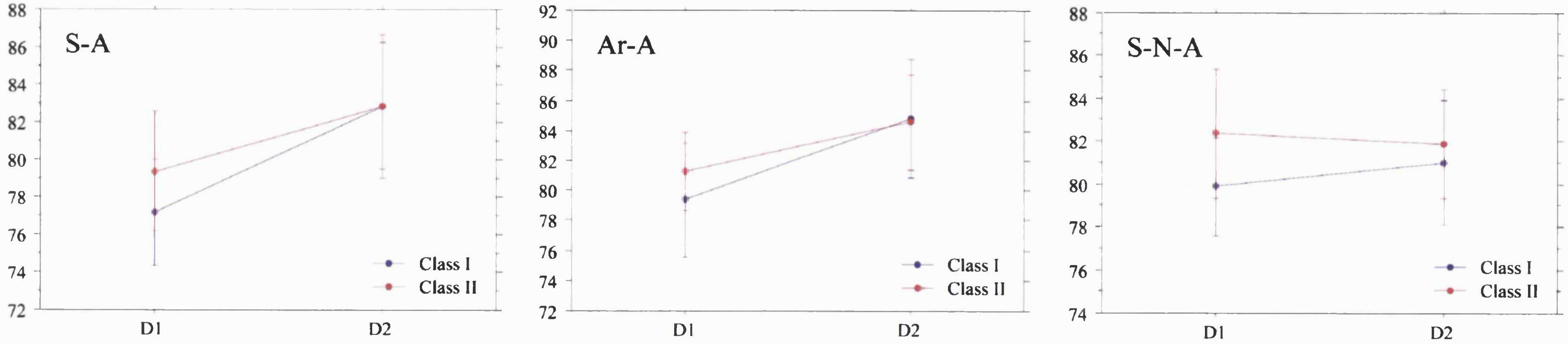

Fig. 4.3. Growth changes in the maxillary skeletal position.

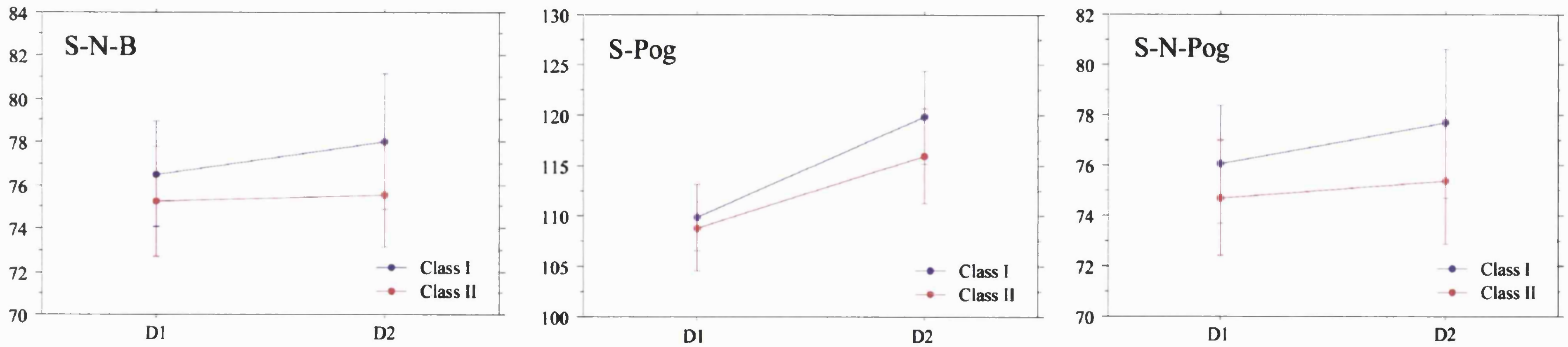

Fig. 4.4. Growth changes in the mandibular skeletal position.

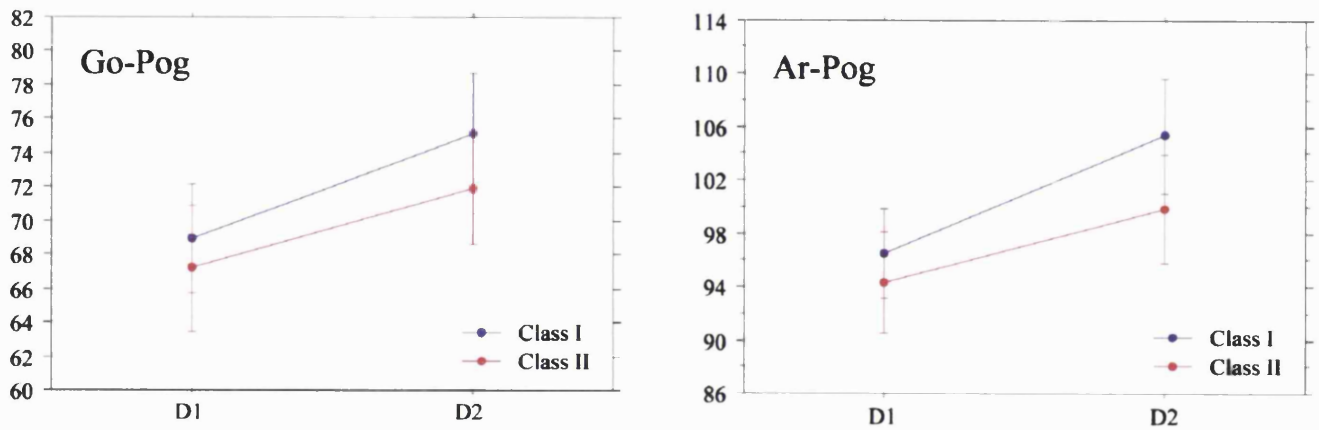

Fig. 4.5. Growth changes in the mandible.

4.2.3 Discussion

Some parameters which indicated significant differences between the groups actually had low values of statistical power due to the shortage of sample numbers (Table 4.5). Ideally, a larger sample was needed for the studies, but to acquire untreated serial records, especially for subjects with skeletal disharmonies is ethically difficult.

The present results showed that there were significant skeletal differences in the maxilla at the stage D1 and in the mandibles at the stage D2; an anterior displaced maxilla was found in the early phase, and a retrognathic mandible in the later phase. Fukuta *et al.* (1996) noted that the frequency of maxillary protrusion for a finger sucking habit group was higher than a non-oral habit group, and the anteriorly displaced maxilla caused by finger sucking habits has been reported (Larsson, 1987; Moore and McDonald, 1997). The anteriorly displaced maxilla was also shown in the present study at D1. At the late mixed dentition, although children usually stop their finger sucking habits (Popovich and Thompson, 1973), the anterior displaced maxilla in the early mixed dentition could restrict the anterior growth of the mandible. Moyers (1988) stated that a Class II skeletal pattern may worsen the occlusal relations with time such that mandibular retrusion in the late mixed dentition may result. Ngan *et al.* (1997a) also noted that a shorter mandibular length and corpus length in a Class II sample were particularly apparent during the pubertal growth period. These findings and the present results indicate that the skeletal Class II mandibles have little growth potential, and more active orthopedic approaches to the mandible during the mixed dentition could possibly be more effective than passive maxillary growth control.

4.2.4 Conclusions

Untreated Japanese girls with skeletal Class II malocclusion had (1) similar growth patterns in cranial and vertical development compared to Class I controls, (2) a protrusive maxilla in the early phase, (3) a retrognathic mandible in the later phase, and (4) less anterior growth of both maxilla and mandible during the mixed dentition compared to Class I controls.

There were some significant differences in the maxillary skeletal relationships at D1 and in the mandibular skeletal relationships at D2 between the Class II subjects and the Class I controls. This suggests that the Class II skeletal growth pattern may have started with maxillary protrusion which settled to a normal anteroposterior position during growth, but the retrusive mandible remained in the later phase of the mixed dentition.

4.3 Craniofacial Morphology of Caucasians with Class II Division 1 Malocclusions (Study 4)

Several investigators have examined the craniofacial features of Class II division 1 malocclusion (Drelich, 1948; Nelson and Higley, 1948; Renfroe, 1948; Gilmore, 1950; Craig, 1951; Riedel, 1952; Blair, 1954; Altemus, 1955; Henry, 1957; Rothstein, 1971; Hitchcock, 1973; Konfino, 1973; Menezes, 1974; Siriwat and Jarabak, 1985; Carter, 1986; Karlsen, 1994; Bishara *et al.*, 1997; Ngan *et al.*, 1997a; Pancherz *et al.*, 1997; Bishara, 1998; Gesch, 2000). The majority of studies have concluded that Class II division 1 malocclusion mainly occurred as a consequence of a retrusive mandible (Drelich, 1948; Renfroe, 1948; Craig, 1951; Riedel, 1952; Henry, 1957; Hitchcock, 1973; Carter, 1986; Karlsen, 1994; Bishara *et al.*, 1997; Ngan *et al.*, 1997a; Pancherz *et al.*, 1997; Bishara, 1998), together with proclination of the upper incisors (Drelich, 1948; Renfroe, 1948; Henry, 1957; Rothstein, 1971; Hitchcock, 1973; Menezes, 1974; Pancherz *et al.*, 1997). However, conflicting results have been reported for the form of the cranial base (Blair, 1954; Rothstein, 1971; Menezes, 1974; Bishara *et al.*, 1997; Ngan *et al.*, 1997a) and the size and form of the mandible (Nelson and Higley, 1948; Gilmore, 1950; Craig, 1951; Altemus, 1955; Henry, 1957; Rothstein, 1971; Menezes, 1974; Ngan *et al.*, 1997a; Bishara, 1998) together with the anteroposterior position of the maxilla (Drelich, 1948; Renfroe, 1948; Craig, 1951; Riedel, 1952; Blair, 1954; Altemus, 1955; Henry, 1957; Rothstein, 1971; Hitchcock, 1973; Konfino, 1973; Carter, 1986; Karlsen, 1994; Bishara *et al.*, 1997; Ngan *et al.*, 1997a; Pancherz *et al.*, 1997; Gesch, 2000). Representative results are shown in Tables 4.6 and 4.7.

Menezes (1974) reported that a shorter anterior cranial base length, a smaller cranial base angle, and shorter mandibular dimensions were found in Class II division 1 females compared with Class I counterparts. On the other hand, Rothstein (1971) reported that a larger anterior cranial base length, a more obtuse cranial base angle, and a normal size and form of the mandible were found in Class II division 1 cases: clearly these authors' conclusions completely conflict with each other.

The purpose of the present study was to further define the morphology of Caucasian skeletal Class II division 1 malocclusions and to compare these features to those of normal Caucasian Class I data.

Table 4.6. Examples of the conflict of findings with regard to anterior cranial base length and cranial base angle in Class II division 1 malocclusions.

		Anterior cranial base length		
		Short	Normal	Long
Cranial base angle	Acute	Menezes 1974		
	Normal		Blair 1954 Bishara *et al.* 1997 Ngan *et al.* 1997	
	Obtuse			Rothstein 1971

Table 4.7. Examples of the conflict of findings with regard to maxillary skeletal position and mandibular dimensions in Class II division 1 malocclusions.

		Maxillary skeletal position		
		Retrusive	Neutral	Protrusive
Mandibular dimensions	Small	Henry 1957	Craig 1951 Ngan *et al.* 1997	
	Normal		Bishara *et al.* 1997	Altemus 1971 Rothstein 1971
	Large			

4.3.1 Material and Methods

4.3.1.1 Subjects

Fifty lateral cephalometric radiographs of British Caucasian girls aged 12 years with Class II division 1 malocclusions and no history of orthodontic treatment were examined. A female sample was randomly selected from the files at the Eastman Dental Hospital, London to avoid the influences based on gender difference. The age range matched those normally presenting for active orthodontic treatment. All the Class II division 1 sample had an A-N-B angle > 5°, an Angle's Class II, at least end-on molar relationship, and an increased overjet as determined by clinical inspection. The control data represented the cephalometric standard values of Class I female Caucasian subjects aged 12 years published by Riolo *et al.* (1974). The mean age of the Class II division 1 sample is shown in Table 4.8 and matched with the Class I data.

Table 4.8. Age distribution of Class II division 1 and Class I Caucasian females.

Present study			Riolo *et al.* (1974)	
Class II division 1			Class I	
N=50			N=27	
Mean	SD	range	Age	range
11y10m	3.5m	11y6m-12y5m	12 years	11y6m-12y5m

4.3.1.2 Cephalometric Analysis

All lateral cephalometric radiographs of the Class II division 1 sample were taken using the same cephalostat system. The magnification of the cephalostats were 7.0% and 12.7% for the test and control data respectively; all linear measurements reported in this study were adjusted accordingly. The lateral cephalometric radiograph of each subject was traced by the same investigator. The selected landmarks were digitised and converted to an x-y co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Fig. 4.6). The 12 linear and 12 angular measurements represented the original parameters and those derived from the analyses of Downs (1948, 1952, 1956), Steiner (1953, 1959, 1960) and Jarabak (Jarabak and Fizzell, 1972). These parameters were compared with those of the Class I standards.

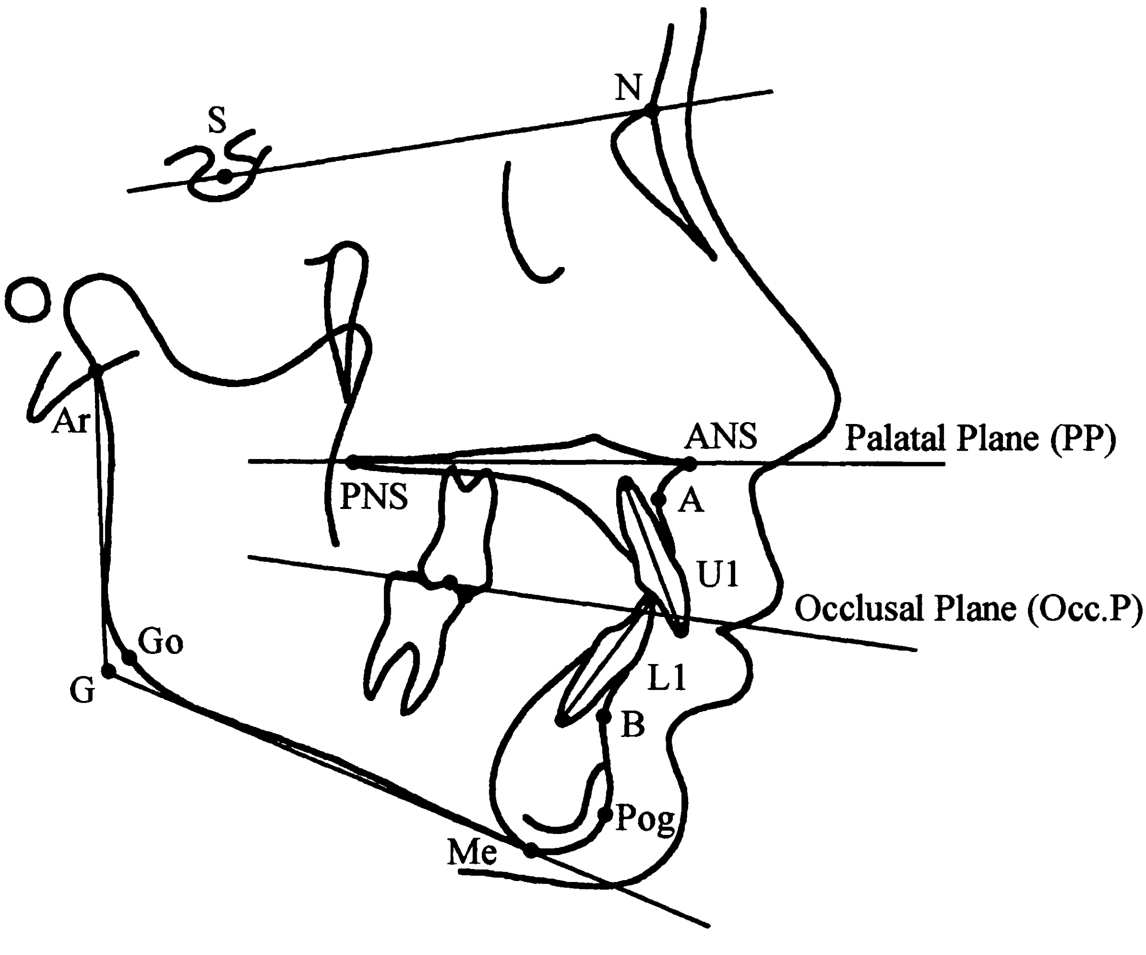

Fig. 4.6. Cephalometric landmarks recorded in Study 4.
- see section 1.2 for definition of landmarks -

4.3.1.3 Error of the Method

All 50 radiographs were re-traced and re-digitised 3 weeks later to examine the error of the method. The coefficient of reliability was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 4.9.

4.3.1.4 Statistical Analysis

Standard descriptive statistics, means and standard deviations, of the cephalometric parameters were calculated. Application of parametric tests for all cephalometric variables was justified since parametric tests had the robustness for distribution (Ichihara, 1990). Equality of variance was tested between each of the groups using the F-test, and differences between groups identified using the unpaired Student's and Welch's *t*-test; the former was applied for the parameters which had equal variances, and the later was applied for those which had unequal variances at the F-test.

4.3.2 Results

The coefficient of reliability for all cephalometric parameters satisfied the level of reliability above 0.90 (Houston, 1983). Comparison between the cephalometric measurements of the Class II division 1 Caucasian girls and the Class I controls is shown in Table 4.9.

4.3.2.1 Cranial Base Relationships

The mean anterior cranial base length (S-N) did not show significant differences in subjects with Class II division 1 malocclusion compared with the control group, but the posterior cranial base length (S-Ar) was significantly longer in Class II division 1 subjects ($p<0.01$). The cranial base angle was evaluated by the N-S-Ar angle. The mean cranial base angle in the Class I controls was mathematically calculated from the mean values of S-N, S-Ar, and N-Ar. The cranial base angle was found to be more obtuse in the Class II division 1 subjects compared with the controls; with the effect that the total cranial base length (N-Ar) was significantly longer in the Class II division 1 subjects ($p<0.05$).

4.3.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla as evaluated by the S-A length and the S-N-A angle did not show a significant difference between the Class II division 1 subjects and the controls. According to the N-ANS length and the angle between the palatal and S-N planes, the maxilla was positioned approximately at the same vertical level in both the test and control groups.

4.3.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by the S-B length and the S-N-B angle. The mandible in the Class II division 1 group indicated a significant retrusive position ($p<0.001$ and $p<0.01$ respectively). The anteroposterior position of the chin as evaluated by S-Pog and the S-N-Pog angle showed a significantly greater retrusion in the Class II division 1 subjects compared with the controls in angular measurement ($p<0.01$), but there was no significant difference in the linear measurement. The vertical position of the mandible was evaluated by the N-Me distance and the S-N/G-Me angle. Both parameters were similar in the test and control groups; there being no significant difference for either parameters. The mean length of the mandibular ramus (Ar-Go), the mandibular body (Go-Pog), and the total mandibular length (Ar-Pog) in the Class II division 1 sample did not show significant differences compared with Class I control subjects. The Class II division 1 malocclusion also had a similar gonial angle (the Ar-G-Me angle) compared with the Class I data.

4.3.2.4 Intermaxillary Relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A-N-B angle. Not surprisingly, it was significantly larger in the Class II division 1 subjects compared with the controls ($p<0.001$) as this was one of the group selection criteria.

The vertical distance between the palatal and mandibular planes in the Class II division 1 sample was not significantly different compared with the Class I standards in both linear (ANS-Me) and angular (the PP/G-Me angle) measurements.

4.3.2.5 Dentoalveolar Relationships

There was no significant difference in dentoalveolar components; the inclination of both upper and lower incisors and the occlusal plane were similar both in subjects with Class II division 1 malocclusions and the Class I controls.

Table 4.9a. Comparison of mean values between Class II division 1 and Class I Caucasian females.

			Present study Class II div.1 (N=50)			Riolo *et al.* (1974) Class I (N=27)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Cranial Base Relationships								
	S-N	(mm)	0.982	65.4	2.8	66.5	2.7	NS
	S-Ar	(mm)	0.983	31.4	3.1	29.3	3.0	**
	N-Ar	(mm)	0.986	88.1	4.1	86.1	3.8	*
	N-S-Ar	(°)	0.982	127.6	4.9	123.2	-	-
Maxillary Skeletal Relationships								
Antero-Posterior	S-A	(mm)	0.989	78.1	3.5	78.1	3.3	NS
	S-N-A	(°)	0.962	81.8	3.2	81.4	3.6	NS
Vertical	N-ANS	(mm)	0.939	48.3	3.0	47.9	3.3	NS
	PP/S-N	(°)	0.924	8.1	3.6	8.3	2.4	NS

The levels of significance are denoted as: no significant difference(NS), p<0.05(*), and p<0.01(**).

Table 4.9b. Comparison of mean values between Class II division 1 and Class I Caucasian females.

			Present study Class II div.1 (N=50)			Riolo *et al.* (1974) Class I (N=27)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Mandibular Skeletal Relationships								
Antero-Posterior	S-B	(mm)	0.989	94.5	5.3	98.7	3.9	***
	S-N-B	(°)	0.977	75.5	3.2	77.7	3.4	**
	S-Pog	(mm)	0.992	106.4	6.1	108.1	4.5	NS
	S-N-Pog	(°)	0.981	76.1	3.4	78.4	3.4	**
Vertical	N-Me	(mm)	0.989	105.8	5.7	105.0	5.3	NS
	S-N/G-Me	(°)	0.992	35.2	5.4	34.1	5.3	NS
Mandible	Ar-Go	(mm)	0.991	39.0	3.9	39.8	3.5	NS
	Go-Pog	(mm)	0.990	67.3	4.8	68.0	3.4	NS
	Ar-Pog	(mm)	0.993	95.0	5.8	96.2	4.4	NS
	Ar-G-Me	(°)	0.985	126.2	7.0	126.2	4.2	NS

The levels of significance are denoted as: no significant difference(NS), $p<0.01$(**), and $p<0.001$(***).

Table 4.9c. Comparison of mean values between Class II division 1 and Class I Caucasian females.

				Present study Class II div.1 (N=50)		Riolo *et al.* (1974) Class I (N=27)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Intermaxillary Relationships								
Antero-Posterior	A-N-B	(°)	0.977	6.3	1.4	3.7	2.4	***
Vertical	ANS-Me	(mm)	0.972	60.4	4.4	59.0	3.4	NS
	PP/G-Me	(°)	0.963	25.8	4.6	25.8	5.1	NS
Dentoalveolar Relationships								
	U1/S-N	(°)	0.954	105.2	8.7	105.6	6.3	NS
	L1/G-Me	(°)	0.982	96.1	6.8	94.7	6.5	NS
	Occ.P/S-N	(°)	0.975	17.4	4.7	16.3	3.3	NS

The levels of significance are denoted as: no significant difference(NS) and $p<0.001$(***). Red colour: tested by Welch's *t*-test

4.3.3 Discussion

Due to lack of truely comparative data, North American Caucasian females with Class I normal occlusions were used as a control for British Caucasian females with Class II division 1 malocclusion. Trenouth *et al.* (1985) and Trenouth *et al.* (1999) reported that the craniofacial morphology of North American and British Caucasian groups were comparable. Therefore, the North American Class I data was considered to be acceptable as the control data. The Class II division 1 sample in the present study could be biased towards severe cases referred for treatment. However, the results shows that these cases did not on average exhibit severe skeletal disharmony. To minimize the error caused by measurements, the landmarks used in this study were carefully chosen; points porion, orbitale, and condylion were not used since poor reproducibility has been reported previously (Cooke and Wei, 1991; Perillo *et al.*, 2000).

From our results, it might be concluded that Caucasian Class II division 1 females had a retrusive mandible, but there was no significant difference in the dimensional parameters of the mandible compared with Class I normal data. Furthermore, there was no significant difference in the gonial angle between the test and control groups. These results indicate that both Class II division 1 and class I subjects had similar mandibles both in size and form. Rothstein (1971) noted that the mandible of Class II division 1 malocclusions was most often within the range of normal for size and form; a result which supports our findings. In studies for Class III malocclusion, investigators have also reported that the size of the mandible was not significantly different compared with Class I standards (Sanborn, 1955; Dietrich, 1970; Chang *et al.,* 1992). It could be concluded that skeletal disharmonies are not caused by the size of the mandible.

The N-S-Ar angle in the test and the controls could not be statistically compared with each other since the control data was mathematically calculated. However, the Class II division 1 sample had a more obtuse N-S-Ar angle compared with the Class I contorols, and it could be mentioned that point Ar in the Class II division 1 sample tended to be placed posteriorly. Thus, the posteriorly positioned mandible could be caused by posterior placement of the temporo-mandibular joint (TMJ) as a relatively obtuse cranial base angle was observed in the Class II division 1 subjects. These results support the views of Hopkin *et al.* (1968), Jarvinen (1984), Kerr and Adams (1988), and Dibbets (1996) who reported that the cranial base angle decreased systematically from Class II, over Class I, to Class III malocclusions.

4.3.4 Conclusions

The characteristic features of Caucasian Class II division 1 malocclusion were as follows: (1) An obtuse cranial base angle. (2) A posteriorly positioned mandible associated with the posteriorly positioned TMJ. (4) Normal size and form of the mandible. (5) Normal vertical development. (6) Normal inclination of incisor axis and occlusal plane.

It would appear that the skeletal disharmony was caused by the posteriorly positioned mandible associated with the posteriorly positioned TMJ.

4.4 Craniofacial Differences between Japanese and Caucasians with Class II Division 1 Malocclusions (Study 5)

Although many investigators have attempted to clarify the morphological features of Japanese and Caucasian Class II division 1 patients (Table 4.10), there are few previous studies that have examined the morphological differences in the craniofacial structure between Japanese and Caucasian patients with Class II division 1 malocclusions (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989). Ono *et al.* (1986) reported that both the maxilla and mandible of Japanese were located more posteriorly than those of Americans, with the Japanese exhibiting greater vertical development. Yamaki (1987) noted that Japanese Class II division 1 patients had a relatively shorter and more posterior positioned maxilla and greater backward rotation of the mandible compared with Caucasian Class II division 1 patients. The author also stated that the differences in the maxillary region between Japanese and Caucasians with Class II division 1 malocclusions were common racial differences, and not specific to Class II division 1 malocclusions. Ishizuka *et al.* (1989) reported that Japanese Class II division 1 patients had a significantly shorter anterior cranial base and maxilla, and evidently more backward rotation of the mandible compared with Caucasians. Despite these investigations, there is still a lack of information regarding the morphological differences between Japanese and Caucasians with Class II division 1 malocclusions.

The purpose of this study was to further define the morphology of Japanese Class II division 1 malocclusions, to compare in features with those of a Caucasian Class II division 1 sample, and to elucidate the differences in craniofacial morphology between both races.

Table 4.10. Previous morphological studies of Class II malocclusion.

Japanese		Caucasians	
		Drelich	1948
		Nelson and Higley	1948
		Renfroe	1948
		Gilmore	1950
		Craig	1951
		Riedel	1952
		Altemus	1955
		Henry	1957
		Blair	1954
Miura *et al.*	1958		
Kuwahara	1968		
Iwasawa *et al.*	1969		
		Rothstein	1971
		Harris *et al.*	1972
		Hitchcock	1973
		Konfino	1973
		Menezes	1974
Iwasawa *et al.*	1980	Moyers *et al.*	1980
		Adams and Kerr	1981
		McNamara	1981
		Anderson and Popovich	1983
		Jarvinen	1984
		Siriwat and Jarabak	1985
Tokuda	1987	Carter	1987
		Bacon *et al.*	1992
		Karlsen	1994
Kasai *et al.*	1995	Rosenblum	1995
		Dibbets	1996
		Baccetti *et al.*	1997
		Pancherz *et al.*	1997

4.4.1 Material and Methods

4.4.1.1 Subjects

The Japanese and Caucasian cephalometric radiographs were selected at random from a private orthodontic practice in Himeji, Japan, and the Eastman Dental Hospital in London, U.K. respectively. As a consequence, the lateral cephalometric radiographs of 49 Japanese and 75 Caucasian girls with Class II division 1 malocclusions with no history of orthodontic treatment were examined. All Japanese and Caucasian subjects had an ANB angle > 5°, an Angle's Class II molar relationship and an increased overjet. The mean age of each group is shown in Table 4.11.

Table 4.11. Age distribution of the Japanese and Caucasian female samples in Study 5.

Japanese Class II division 1			Caucasian Class II division 1		
N=49			N=75		
Mean	SD	range	Mean	SD	range
11y8m	6.9m	11y0m-12y11m	11y11m	6.2m	11y0m-12y11m

4.4.1.2 Cephalometric Analysis

All lateral cephalometric radiographs were taken using the same cephalostat for each group. The Japanese and Caucasian radiographs had an image magnification of 10 and 7 percent respectively. All linear measurements reported in this study were adjusted accordingly. The lateral cephalometric radiographs of each subject were traced by the same investigator. The selected landmarks were digitised and converted to an x-y co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Fig. 4.7). In this study, points Po and Or were not used since poor reproducibility has been previously reported (Cooke and Wei, 1991). The 13 linear and 13 angular measurements mostly derived from the analyses of Steiner (1953, 1959, 1960) and Jarabak (Jarabak and Fizzell, 1972) were used in this study.

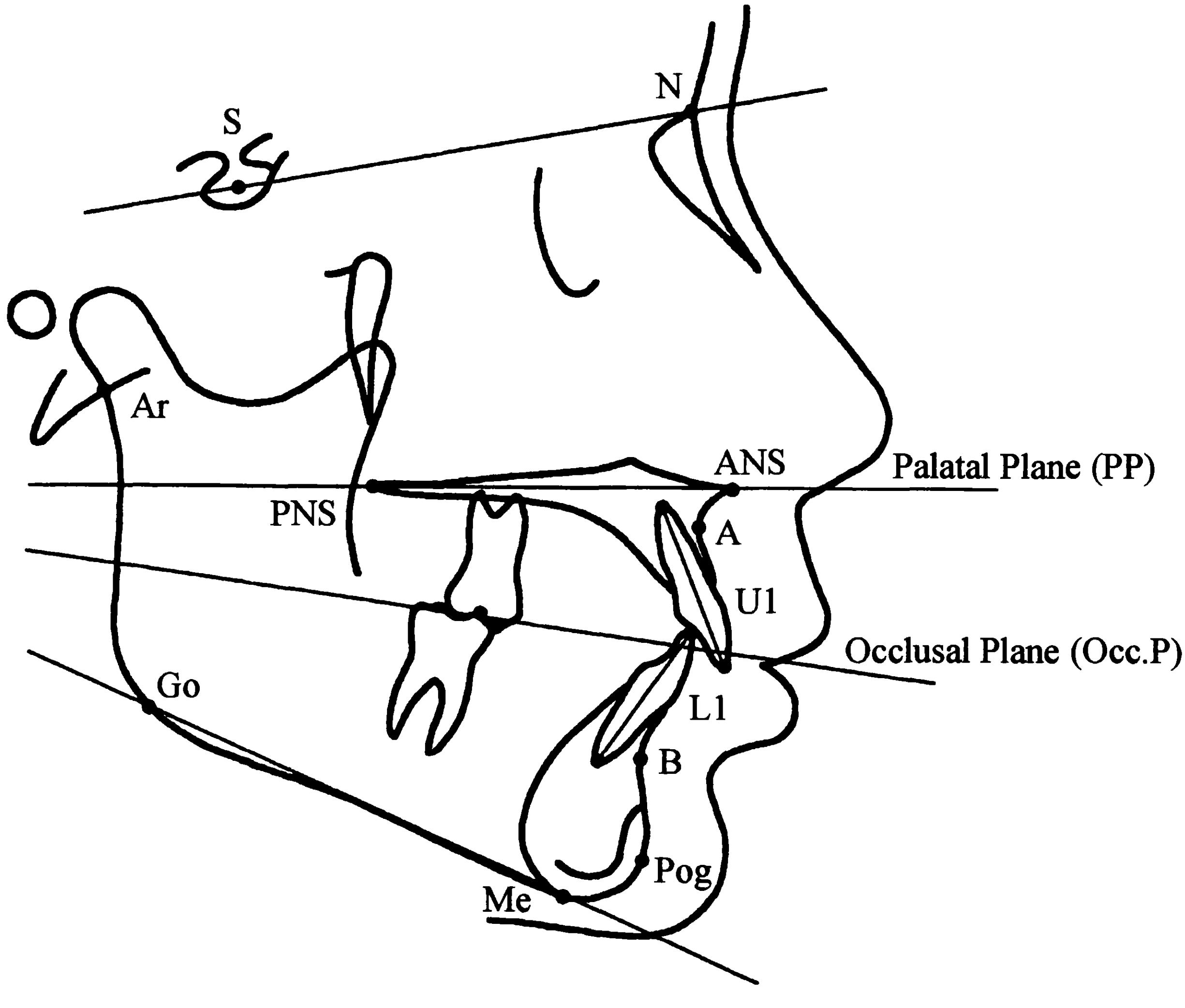

Fig. 4.7. Cephalometric landmarks recorded in Study 5.
- see section 1.2 for definition of landmarks -

4.4.1.3 Error of the Method

All 124 lateral head films were traced twice. The second tracing was carried out 3 weeks later. The error of the method was determined using the coefficient of reliability, which was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983).The results are presented in Table 4.12.

4.4.1.4 Statistical Analysis

Means and standard deviations of all parameters were calculated. The D'Agostino-Pearson test was used to test for normality of distribution in the cephalometric variables prior to using parametric tests. Equality of variance was tested between each of the groups. The unpaired Student's and Welch's *t*-test were applied to each parameter to identify the differences between groups; the former was applied for the parameters which had equal variances, and the later was applied for those that had unequal variances at the F-test.

4.4.2 Results

The coefficient of reliability for all cephalometric parameters indicated values within the range between 0.912 and 0.996, and satisfied the level of reliability (>0.90) (Houston, 1983). Comparison between the cephalometric measurements of Japanese and Caucasian girls with Class II division 1 malocclusions are shown in Table 4.12 and Figure 4.8.

4.4.2.1 Cranial Base Relationships

The mean anterior (S-N) and total cranial base length (N-Ar) were significantly shorter in Japanese subjects compared with Caucasians ($p<0.001$). However, the posterior cranial base length (S-Ar) and the saddle angle (N-S-Ar) did not show significant differences between the groups.

4.4.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla was evaluated using S-A, Ar-A, and the S-N-A angle. The linear parameters, S-A and Ar-A, showed a significantly more protrusive maxilla in the Caucasian sample compared with the Japanese ($p<0.001$), but the S-N-A angle did not indicate a significant difference between both groups. According to the N-ANS distance, the Japanese had a significantly larger anterior upper facial height ($p<0.05$). The PP/S-N angle was slightly larger in Japanese subjects although the difference was not significant.

4.4.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by S-B and the S-N-B angle. According to these parameters, there was no significant difference in the anteroposterior position of mandible between Japanese and Caucasians. The anteroposterior position of the chin (S-Pog and the S-N-Pog angle) also showed no significant difference between the Japanese and the Caucasian sample. The vertical position of the mandible was evaluated using N-Me, and angles S-N/Go-Me and S-Ar-Go. All these parameters in the Japanese group indicated significantly more vertical development compared with Caucasians ($p<0.01$, $p<0.001$, and $p<0.001$ respectively). The mean length of the mandibular ramus (Ar-Go) showed no significant difference between the groups, but the mandibular body (Go-Pog) and the total mandibular length (Ar-Pog) in the Caucasian sample was significantly longer compared with the Japanese sample ($p<0.05$). Both groups had a similar gonial angle (Ar-Go-Me).

4.4.2.4 Intermaxillary Relationships

There was no significant difference between the groups in the anteroposterior relationship between the maxilla and mandible (ANB angle). The vertical height was evaluated by the ANS-Me distance and the PP/Go-Me angle. According to these measurements, the Japanese subjects had a significantly larger anterior lower facial height ($p<0.05$, $p<0.001$ respectively).

4.4.2.5 Dentoalveolar Relationships

The inclination of the upper incisors was similar in both groups, but the lower incisors in the Japanese subjects were significantly more proclined compared with the Caucasian group. The occlusal plane inclination in the Japanese was significantly steeper compared with the Caucasians ($p<0.01$).

Table 4.12a. Comparison of mean values between Japanese and Caucasian females with Class II division 1 malocclusion.

			Japanese Class II div.1 (N=49)			Caucasian Class II div.1 (N=75)			
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Significance
Cranial Base Relationships									
	S-N	(mm)	0.961	61.4	2.4	0.978	65.4	2.7	***
	S-Ar	(mm)	0.978	32.1	2.4	0.981	31.6	2.8	NS
	N-Ar	(mm)	0.987	84.6	3.8	0.985	88.3	3.8	***
	N-S-Ar	(°)	0.982	126.8	4.4	0.987	127.6	5.3	NS
Maxillary Skeletal Relationships									
Antero-Posterior	S-A	(mm)	0.912	75.9	3.1	0.991	78.3	3.5	***
	Ar-A	(mm)	0.968	78.2	3.5	0.994	81.9	4.5	***
	S-N-A	(°)	0.985	82.0	3.2	0.967	81.7	3.3	NS
Vertical	N-ANS	(mm)	0.955	49.6	2.6	0.944	48.5	2.8	*
	PP/S-N	(°)	0.946	9.1	2.9	0.937	8.2	3.5	NS

Levels of significance are denoted as: no significant difference(NS), $p<0.05$(*), and $p<0.001$(***).

Table 4.12b. Comparison of mean values between Japanese and Caucasian females with Class II division 1 malocclusion.

			Japanese class II div.1 (N=49)			Caucasian class II div.1 (N=75)			
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Significance
Mandibular Skeletal Relationships									
Antero-Posterior	S-B	(mm)	0.985	95.6	4.4	0.989	94.9	4.8	NS
	S-N-B	(°)	0.987	75.9	3.1	0.977	75.4	3.1	NS
	S-Pog	(mm)	0.994	107.1	5.0	0.992	106.7	5.6	NS
	S-N-Pog	(°)	0.981	75.2	3.0	0.984	76.0	3.4	NS
Vertical	N-Me	(mm)	0.995	109.4	5.6	0.991	106.4	5.7	**
	S-N/Go-Me	(°)	0.988	41.1	5.2	0.993	37.0	5.6	***
	S-Ar-Go	(°)	0.966	143.5	5.1	0.982	139.2	7.4	***
Mandible	Ar-Go	(mm)	0.971	38.1	3.7	0.989	39.2	3.9	NS
	Go-Pog	(mm)	0.965	66.0	3.5	0.988	67.6	4.5	*
	Ar-Pog	(mm)	0.996	93.0	4.6	0.994	95.1	5.5	*
	Ar-Go-Me	(°)	0.969	130.8	5.7	0.986	130.2	6.4	NS

Levels of significance are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***). Red colour: tested by Welch's *t*-test

Table 4.12c. Comparison of mean values between Japanese and Caucasian females with Class II division 1 malocclusion.

			Japanese class II div.1 (N=49)			Caucasian class II div.1 (N=75)			
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Significance
Intermaxillary Relationships									
Antero-Posterior	A-N-B	(°)	0.952	6.1	1.0	0.975	6.3	1.4	NS
Vertical	ANS-Me	(mm)	0.982	62.6	4.6	0.979	60.9	4.5	*
	PP/Go-Me	(°)	0.981	32.0	5.1	0.973	28.9	4.7	***
Dentoalveolar Relationships									
	U1/S-N	(°)	0.974	107.3	6.6	0.956	105.0	7.9	NS
	L1/Go-Me	(°)	0.986	96.6	4.8	0.980	94.3	6.6	*
	Occ.P/S-N	(°)	0.960	20.0	3.4	0.979	17.5	4.5	**

Levels of significance are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***). Red colour: tested by Welch's *t*-test

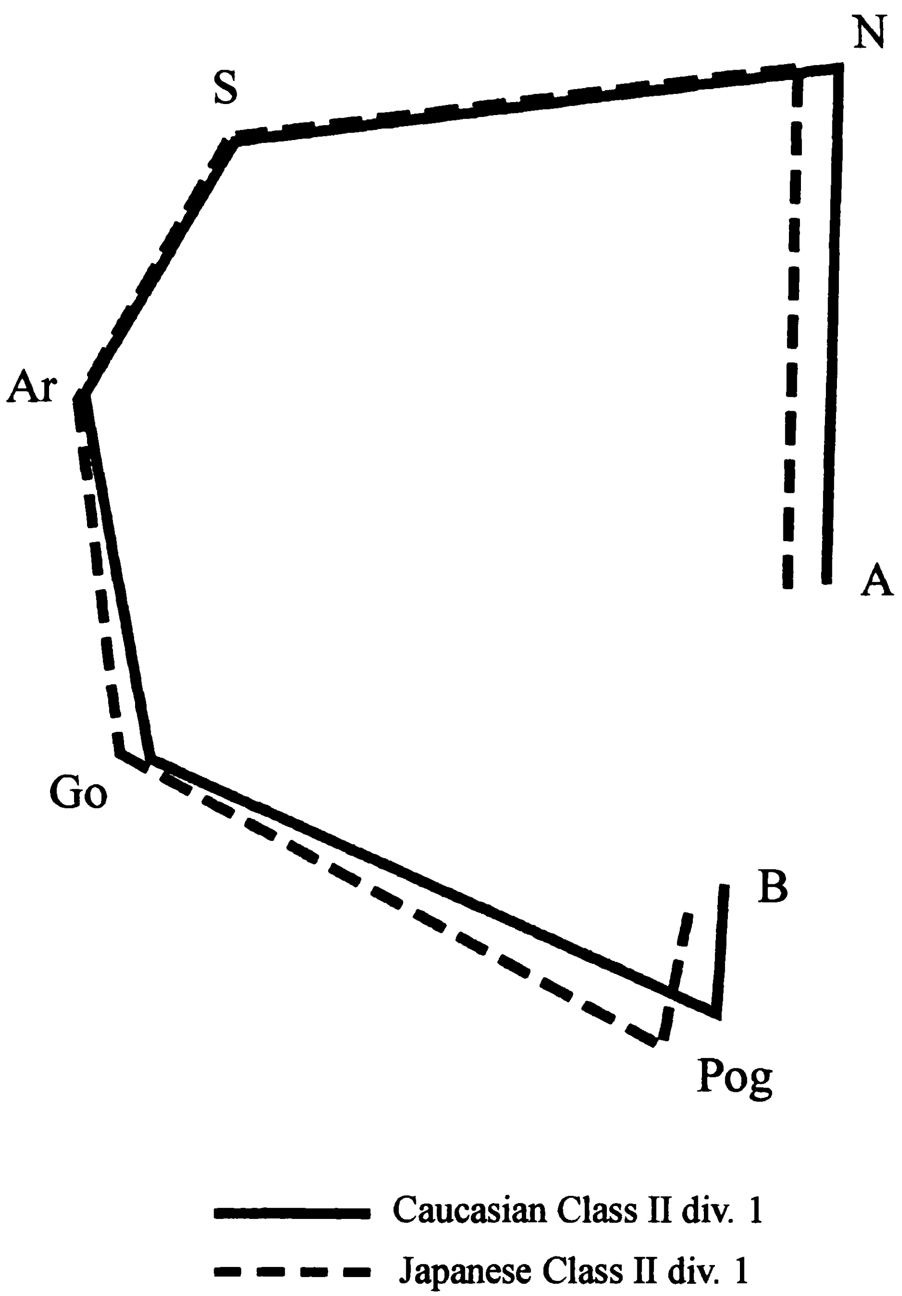

Fig. 4.8 Comparison between representative landmarks of the mean Japanese and Caucasian samples with Class II division 1 malocclusions.

4.4.3 Discussion

The short anterior cranial base length in the Japanese Class II division 1 sample does not represent a specific morphological feature of the Class II division 1 malocclusion but rather a feature of Japanese in general. Masaki (1980) reported that Japanese Class I patients had a significantly shorter anterior cranial base length when compared with Caucasian counterparts. Cooke and Wei (1989) also reported that southern Chinese boys had a significantly shorter anterior cranial base length compared with Caucasian boys. Thus, a short anterior cranial base could be a racial feature of an Asian population who have a brachycephalic skeletal pattern. All previous studies have reported that Japanese patients have more excessive vertical skeletal development compared with Caucasians in both Class I (Masaki, 1980; Nezu *et al.*, 1982; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996) and Class II division 1 malocclusions (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989). Although a steeper mandibular plane has been reported in Japanese Class II studies (Miura *et al.*, 1958; Kuwahara, 1968; Iwasawa *et al.*, 1969, 1980; Ishii *et al.*, 2000), previous racial comparisons have concluded that there is no significant difference in the form and size of the mandible between Japanese and Caucasians for both Class I (Masaki, 1980; Miyajima *et al.*, 1996) and Class II division 1 malocclusions (Ishizuka *et al.*, 1989). Although a shorter length of the mandibular body and total mandibular length were shown in Japanese subjects in this study, these findings could not be the conclusive differences since low significance ($p<0.05$) was calculated. The high-angle facial pattern of Japanese Class II division 1 could be related to the more obtuse articular angle, leading to a greater backward rotation of the mandible rather than an effect of the form of the mandible. Therefore, the intermaxillary disharmony seen in Japanese Class II division 1 cases may be a feature of the vertical problem associated with a backward rotation of the mandible, whereas in Caucasians this disharmony may reflect a horizontal problem associated with an anteriorly positioned maxilla.

In the light of these findings, orthodontic treatment mechanics for Class II division 1 malocclusions should be considered depending on race. Nezu *et al.* (1982) stated the chin control and vertical control of bite opening in orthodontic treatment was more important for Japanese patients since that population had a tendency for facial axis opening. An antero-posterior force may be more appropriate for Class II Caucasian malocclusions.

4.4.4 Conclusions

The morphological differences between Japanese and Caucasians with Class II division 1 malocclusion are as follows: (1) Caucasians had significantly longer anterior cranial base length and slightly longer mandibular body length (2) Japanese had a significantly more obtuse articular angle, significantly steeper mandibular and occlusal plane angles, high-angle facial pattern, and significantly more proclined lower incisors.

Class II division 1 maxillary protrusion in Japanese girls may represent a vertical problem, whereas in Caucasians it may be more indication of a horizontal problem. The backward rotation of the mandible associated with Japanese and the anteriorly positioned maxilla in Caucasians could be the main reasons for the intermaxillary disharmony.

CHAPTER 5

Class III Malocclusion

5.1 Craniofacial Morphology of Japanese with Surgical Class III Malocclusions (Study 6)

A larger proportion of patients with Class III malocclusions are treated in Japan and other Asian countries compared with Western countries due to the relatively high prevalence of such abnormality in Asian populations (Chan, 1974; Ishii *et al.*, 1987; Lew and Foong, 1993; Baik *et al.*, 2000). In our global world, characterization of Class III malocclusion is thus important for not only Asian but also Western orthodontists. Several investigators have described the morphological traits of Class III malocclusions (Stapf, 1948; Sanborn, 1955; Maj *et al.*, 1958; Pascoe *et al.*, 1960; Mills, 1966; Susami, 1967; Horowitz *et al.*, 1969; Iwasawa *et al.*, 1969; Ahlgren, 1970; Dietrich, 1970; Rakosi, 1970; Ridell *et al.*, 1971; Chan, 1974; Jacobson *et al.*, 1974; Sawa, 1978; Sakai *et al.*, 1980; Yamazaki and Iwasawa, 1981; Sugawara *et al.*, 1983; Ellis and McNamara, 1984; Kiyama *et al.*, 1984; Guyer *et al.*, 1986; Motoyoshi *et al.*, 1986; Williams and Andersen, 1986; Yamazaki, 1988; Toms, 1989; Chang *et al.*, 1992; Mackay *et al.*, 1992; Martone *et al.*, 1992; Battagel, 1993; Lew and Foong, 1993; Lu *et al.*, 1993; Tollaro *et al.*, 1994; Kao *et al.*, 1995; Dibbets, 1996; Ngan *et al.*, 1997b; Baik *et al.*, 2000; Bandai *et al.*, 2000; Kurokawa *et al.*, 2000). Most previous investigators concluded that Class III patients have a protrusive mandible (Sanborn, 1955; Mills, 1966; Susami, 1967; Horowitz *et al.*, 1969; Iwasawa *et al.*, 1969;

Ahlgren, 1970; Rakosi, 1970; Ridell *et al.*, 1971; Jacobson *et al.*, 1974; Sawa, 1978; Sugawara *et al.*, 1983; Ellis and McNamara, 1984; Kiyama *et al.*, 1984; Guyer *et al.*, 1986; Motoyoshi *et al.*, 1986; Williams and Andersen, 1986; Yamazaki, 1988; Toms, 1989; Chang *et al.*, 1992; Baik *et al.*, 2000; Bandai *et al.*, 2000), a normal mandibular ramus length (Sanborn, 1955; Ridell *et al.*, 1971; Jacobson *et al.*, 1974; Sawa, 1978; Guyer *et al.*, 1986; Williams and Andersen, 1986; Yamazaki, 1988; Chang *et al.*, 1992), an obtuse gonial angle (Sanborn, 1955; Maj *et al.*, 1958; Horowitz *et al.*, 1969; Iwasawa *et al.*, 1969; Ahlgren, 1970; Dietrich, 1970; Rakosi, 1970; Ridell *et al.*, 1971; Jacobson *et al.*, 1974; Yamazaki and Iwasawa, 1981; Kiyama *et al.*, 1984; Guyer *et al.*, 1986; Yamazaki, 1988; Toms, 1989; Chang *et al.*, 1992; Baik *et al.*, 2000; Kurokawa *et al.*, 2000), proclined upper incisors (Sanborn, 1955; Susami, 1967; Ahlgren, 1970; Jacobson *et al.*, 1974; Sawa, 1978; Ellis and McNamara, 1984; Guyer *et al.*, 1986; Baik *et al.*, 2000) and retroclined lower incisors (Sanborn, 1955; Maj *et al.*, 1958; Susami, 1967; Iwasawa *et al.*, 1969; Ahlgren, 1970; Dietrich, 1970; Jacobson *et al.*, 1974; Ellis and McNamara, 1984; Guyer *et al.*, 1986; Yamazaki, 1988; Chang *et al.*, 1992; Baik *et al.*, 2000). However, there is controversy with regard to the reported values of some of these cephalometric parameters in Class III malocclusion cases. For example, a shorter anterior cranial base length (Sanborn, 1955; Susami, 1967; Horowitz *et al.*, 1969; Chan, 1974; Sawa, 1978; Yamazaki and Iwasawa, 1981; Sugawara *et al.*, 1983; Kiyama *et al.*, 1984; Yamazaki, 1988; Tollaro *et al.*, 1994;

Dibbets, 1996; Baik *et al.*, 2000), a retrusive maxilla (Sanborn, 1955; Mills, 1966; Susami, 1967; Ahlgren, 1970; Rakosi, 1970; Jacobson *et al.*, 1974; Ellis and McNamara, 1984; Guyer *et al.*, 1986; Williams and Andersen, 1986; Toms, 1989; Chang *et al.*, 1992; Tollaro *et al.*, 1994; Kao *et al.*, 1995) and a longer mandibular body length have been reported by some investigators (Rakosi, 1970; Ridell *et al.*, 1971; Jacobson *et al.*, 1974; Sawa, 1978; Sugawara *et al.*, 1983; Kiyama *et al.*, 1984; Lu *et al.*, 1993; Tollaro *et al.*, 1994; Bandai *et al.*, 2000; Kurokawa *et al.*, 2000), while others have reported a normal anterior cranial base length (Ridell *et al.*, 1971; Guyer *et al.*, 1986; Toms, 1989; Chang *et al.*, 1992; Lu *et al.*, 1993; Bandai *et al.*, 2000; Kurokawa *et al.*, 2000), normal positioned maxilla (Iwasawa *et al.*, 1969; Ridell *et al.*, 1971; Yamazaki and Iwasawa, 1981; Sugawara *et al.*, 1983; Motiyoshi *et al.*, 1986; Yamazaki, 1988; Lu *et al.*, 1993; Baik *et al.*, 2000; Bandai *et al.*, 2000) and normal mandibular body length (Sanborn, 1955; Horowitz *et al.*, 1969; Guyer *et al.*, 1986; Williams and Andersen, 1986; Chang *et al.*, 1992) in such patients.

Williams and Andersen (1986) found a retrognathic maxilla in Class III children and reported no significant difference in the size of the mandible between Class III and Class I groups. They concluded that the skeletal Class III pattern was the result of a retrusive maxilla and an anteriorly positioned glenoid fossa. Guyer *et al.* (1986) reported that Class III juveniles and adolescents had a similar size of the mandibular ramus and body compared with Class I normal groups, but they had a longer total mandibular length associated with a more obtuse gonial angle. They also described the maxilla as retrusive and reported a normal antero-posterior position of the temporo-mandibular joint (TMJ) in the Class III sample. A retrusive maxilla and a longer total mandibular length were their key findings in skeletal Class III pattern. Yamazaki and Iwasawa (1981) reported that Class III adult Japanese have a larger mandible with more obtuse gonial angle compared with Class I controls, but they did not find appreciable differences in the maxilla between the groups. According to their study, the Class III skeletal pattern is a result of an excessive development of the mandible.

Prediction of the facial growth pattern is very important in the treatment of Class III malocclusion. Untreated adults with severe skeletal Class III malocclusions are a typical result of the Class III growth pattern. However, their morphological characteristics are still unclear, and there are only a few studies (Yamazaki and Iwasawa, 1981; Motoyoshi *et al.*, 1986; Yamazaki, 1988) that have previously carefully examined the morphological features of adult Japanese with surgical Class III malocclusion compared with Class I normal occlusion although several studies on Japanese Class III (Susami, 1967; Iwasawa *et al.*, 1969; Sawa, 1978; Sakai *et al.*, 1980; Sugawara *et al.*, 1983; Kiyama *et al.*, 1984; Lu *et al.*, 1993; Bandai *et al.*, 2000; Kurokawa *et al.*, 2000) have been published.

The purpose of the present study was to further define the facial morphological features of young adult Japanese females with surgical Class III malocclusion and to compare these features to those of Japanese females with Class I normal occlusion.

5.1.1 Material and Methods

5.1.1.1 Subjects

Lateral cephalograms of 28 untreated Japanese females diagnosed with skeletal Class III malocclusion (mean age, 19.6 years) were examined. Only female subjects were selected at random from the patient database at the Department of Orthodontics, Matsumoto Dental University, to avoid gender difference in our analysis. The criteria for selection included (1) young adult Japanese female, (2) no previous history of any orthodontic treatments, (3) treatment planned for orthognathic surgery, (4) Angle's Class III molar relationships, and (5) negative A-N-B angle. The control subjects were 26 Japanese females aged between 23 and 27 with Class I normal occlusion. All the control subjects selected from 150 undergraduate students at the Matsumoto Dental University, Japan were not a true selected sample but was representative of a cross-section of non-growing Japanese as X-ray taken by the dental students. The control sample had an Angle's Class I molar relationship with an acceptable profile and an A-N-B angle >1° but < 4°, since the reported normal A-N-B angle for Japanese population is 3° (Uesato *et al.*, 1978).

5.1.1.2 Cephalometric Analysis

All lateral cephalometric radiographs of the test and control subjects were obtained using the same cephalostat system. The magnification of the cephalostat was 10.0%, and all linear measurements reported in this study were enlarged by a factor of 10.0%. The lateral cephalometric radiograph of each subject was traced by the same investigator. The selected landmarks were digitized and converted to an x-y co-ordinate system (Fig. 5.1). The 14 linear and 13 angular measurements represented the original parameters and those derived from the analyses of Steiner (Steiner, 1953, 1959, 1960) and Jarabak (Jarabak and Fizzell, 1972). The parameters of subjects with surgical Class III malocclusion were compared with those of the Class I normal group.

5.1.1.3 Error of the Method

54 cephalograms were re-traced and re-digitized 3 weeks later to examine the error of the measurement. The coefficient of reliability was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results of analysis of each parameter and the corresponding coefficient of reliability are presented in Table 5.1.

5.1.1.4 Statistical Analysis

All cephalometric parameters are expressed as the mean and standard deviation for each group. Differences in each cephalometric parameter between the test and control

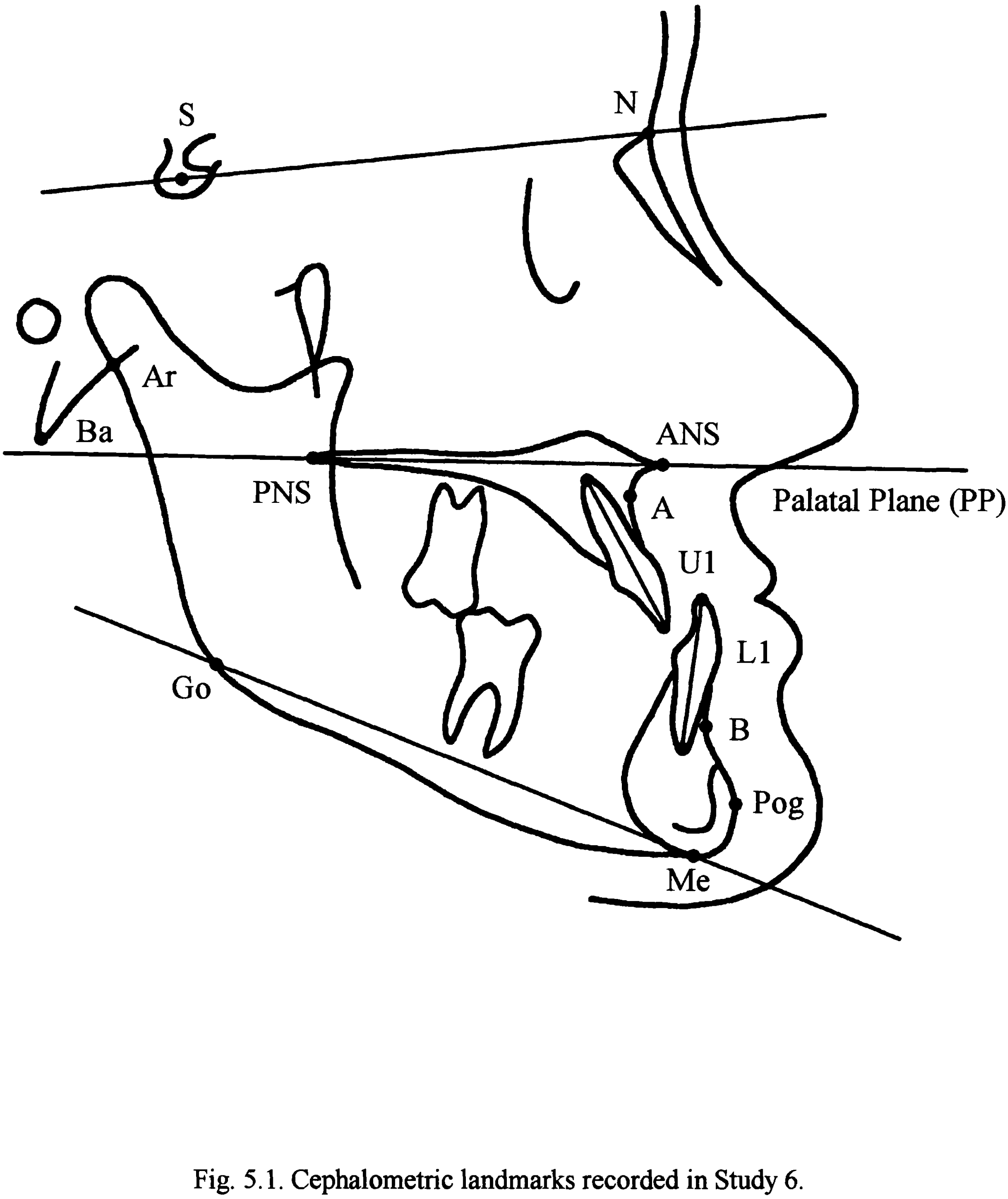

Fig. 5.1. Cephalometric landmarks recorded in Study 6.
- see section 1.2 for definition of landmarks -

groups were tested for statistical significance using a non-parametric test (Mann-Whitney test) due to the small sample size.

5.1.2 Results

The coefficient of reliability for all cephalometric parameters satisfied the level of reliability above 0.90 (Houston, 1983). The results of comparison of cephalometric measurements of surgical Class III subjects and Class I controls are shown in Table 5.1 and Figure 5.2.

5.1.2.1 Cranial Base Relationships

The cranial base relationships were examined by S-N, S-Ar, N-Ar, the N-S-Ar and N-S-Ba angles. The mean anterior cranial base length (S-N) was slightly shorter in subjects with surgical Class III malocclusion compared with the control group. The mean posterior cranial base length (S-Ar) and mean total cranial base length (N-Ar) were significantly shorter in surgical Class III subjects than the controls ($p<0.01$). The cranial base angle was evaluated by the N-S-Ar and N-S-Ba angles. The saddle angle (the N-S-Ar angle) was smaller in the test group compared with the control ($p<0.05$), but the N-S-Ba angle was not significantly different between the test and control groups.

5.1.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla was evaluated by S-A, Ar-A and the S-N-A angle. The linear parameters, S-A and Ar-A, indicated a more retrusive maxilla in the surgical Class III group ($p<0.01$ and $p<0.001$, respectively), but the angular parameter was not significantly different between the two groups. Based on the upper anterior facial height (N-ANS) and the angle between the palatal and S-N planes, the maxilla was positioned approximately at the same vertical level in both test and control groups.

5.1.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by S-B and the S-N-B angle. The mandible in the surgical Class III group showed a significant protrusive position ($p<0.001$). The anteroposterior position of the chin as evaluated by S-Pog and S-N-Pog angle also indicated a significantly prominent protrusion in subjects with surgical Class III malocclusion compared with the controls ($p<0.001$). The vertical position of the mandible was evaluated by N-Me, S-Go, the S-N/Go-Me and S-Ar-Go angles. The total anterior facial height (N-Me) was not significantly different in the two groups, but the posterior facial height (S-Go) was significantly shorter in the test group than the control. The mandibular plane angle (the S-N/Go-Me angle) in the surgical Class III subjects was significantly steeper compared with the controls, but the articular angle (the S-Ar-Go angle) was similar in the two groups. The form of the mandible was examined by Ar-Go, Go-Pog, Ar-Pog and the Ar-Go-Me angle. The mean length of the mandibular ramus (Ar-Go) in the surgical Class III group was not significantly different from the controls, but the mandibular body (Go-Pog) and total mandibular length (Ar-Pog) were significantly longer in subjects with surgical Class III than the controls ($p<0.05$ and $p<0.001$, respectively). The test group also had a significantly more obtuse gonial angle (the Ar-Go-Me angle) compared with the controls.

5.1.2.4 Intermaxillary Relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A-N-B angle. Not surprisingly, the angle was significantly smaller in the surgical Class III subjects compared with the controls ($p<0.001$), as this was one of the group selection criteria. The vertical distance between the palatal and mandibular planes was examined by ANS-Me and the PP/Go-Me angle. The test group had a significantly longer lower anterior facial height (ANS-Me) and a steeper PP/Go-Me angle compared with the controls ($p<0.05$ and $p<0.01$, respectively).

5.1.2.5 Dentoalveolar Relationships

The inclination of both upper and lower incisors was also examined. Subjects with surgical Class III malocclusion had significantly retroclined lower incisors compared with Class I control subjects ($p<0.001$), but the inclination of the upper incisors was similar.

Table 5.1a. Comparison of mean values between surgical Class III and Class I Japanese females.

			Surgical Class III N=28			Class I N=26			
			coefficient of reliability	Mean	S.D.	coefficient of reliability	Mean	S.D.	Significance
Cranial Base Relationships									
	S-N	(mm)	0.992	68.8	3.4	0.988	70.3	2.7	NS
	S-Ar	(mm)	0.950	34.5	3.7	0.985	39.3	3.7	***
	N-Ar	(mm)	0.956	92.5	4.5	0.990	99.1	4.9	***
	N-S-Ar	(°)	0.974	123.8	5.5	0.987	127.2	5.3	*
	N-S-Ba	(°)	0.973	131.6	4.8	0.983	132.6	4.7	NS
Maxillary Skeletal Relationships									
Antero-Posterior	S-A	(mm)	0.990	84.5	4.4	0.985	87.5	3.1	**
	Ar-A	(mm)	0.983	84.0	4.0	0.996	90.4	4.9	***
	S-N-A	(°)	0.987	80.1	4.2	0.986	81.5	3.0	NS
Vertical	N-ANS	(mm)	0.967	56.6	2.8	0.956	58.1	2.3	NS
	PP/S-N	(°)	0.949	10.0	3.5	0.962	9.6	3.0	NS

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***).

Table 5.1b. Comparison of mean values between surgical Class III and Class I Japanese females.

			Surgical Class III N=28			Class I N=26			
			coefficient of reliability	Mean	S.D.	coefficient of reliability	Mean	S.D.	Significance
Mandibular Skeletal Relationships									
Antero-Posterior	S-B	(mm)	0.989	123.4	5.9	0.981	115.3	4.5	***
	S-N-B	(°)	0.991	84.3	4.7	0.985	79.0	3.0	***
	S-Pog	(mm)	0.996	138.4	7.1	0.995	130.1	5.2	***
	S-N-Pog	(°)	0.990	84.3	4.8	0.985	79.3	3.1	***
Vertical	N-Me	(mm)	0.999	132.3	8.2	0.987	129.2	4.7	NS
	S-Go	(mm)	0.975	79.5	5.3	0.993	84.9	4.8	***
	S-N/Go-Me	(°)	0.996	40.9	6.1	0.994	35.4	5.2	**
	S-Ar-Go	(°)	0.944	139.2	7.3	0.990	142.1	7.5	NS
Mandible	Ar-Go	(mm)	0.939	50.3	4.5	0.992	50.6	4.3	NS
	Go-Pog	(mm)	0.968	84.5	5.3	0.987	81.1	4.4	*
	Ar-Pog	(mm)	0.996	123.6	6.1	0.997	114.8	5.7	***
	Ar-Go-Me	(°)	0.968	137.9	7.1	0.985	126.0	6.8	***

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***).

Table 5.1c. Comparison of mean values between surgical Class III and Class I Japanese females.

			Surgical Class III N=28			Class I N=26			
			coefficient of reliability	Mean	S.D.	coefficient of reliability	Mean	S.D.	Significance
Intermaxillary Relationships									
Antero-Posterior	A-N-B	(°)	0.993	-4.2	2.4	0.980	2.5	0.8	***
Vertical	ANS-Me	(mm)	0.996	76.1	7.1	0.994	72.5	4.2	*
	PP/Go-Me	(°)	0.989	30.8	6.4	0.989	25.8	4.9	**
Dentoalveolar Relationships									
	U1/S-N	(°)	0.997	110.3	6.6	0.993	106.5	6.1	NS
	L1/Go-Me	(°)	0.999	75.0	7.4	0.995	94.2	8.7	***

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***).

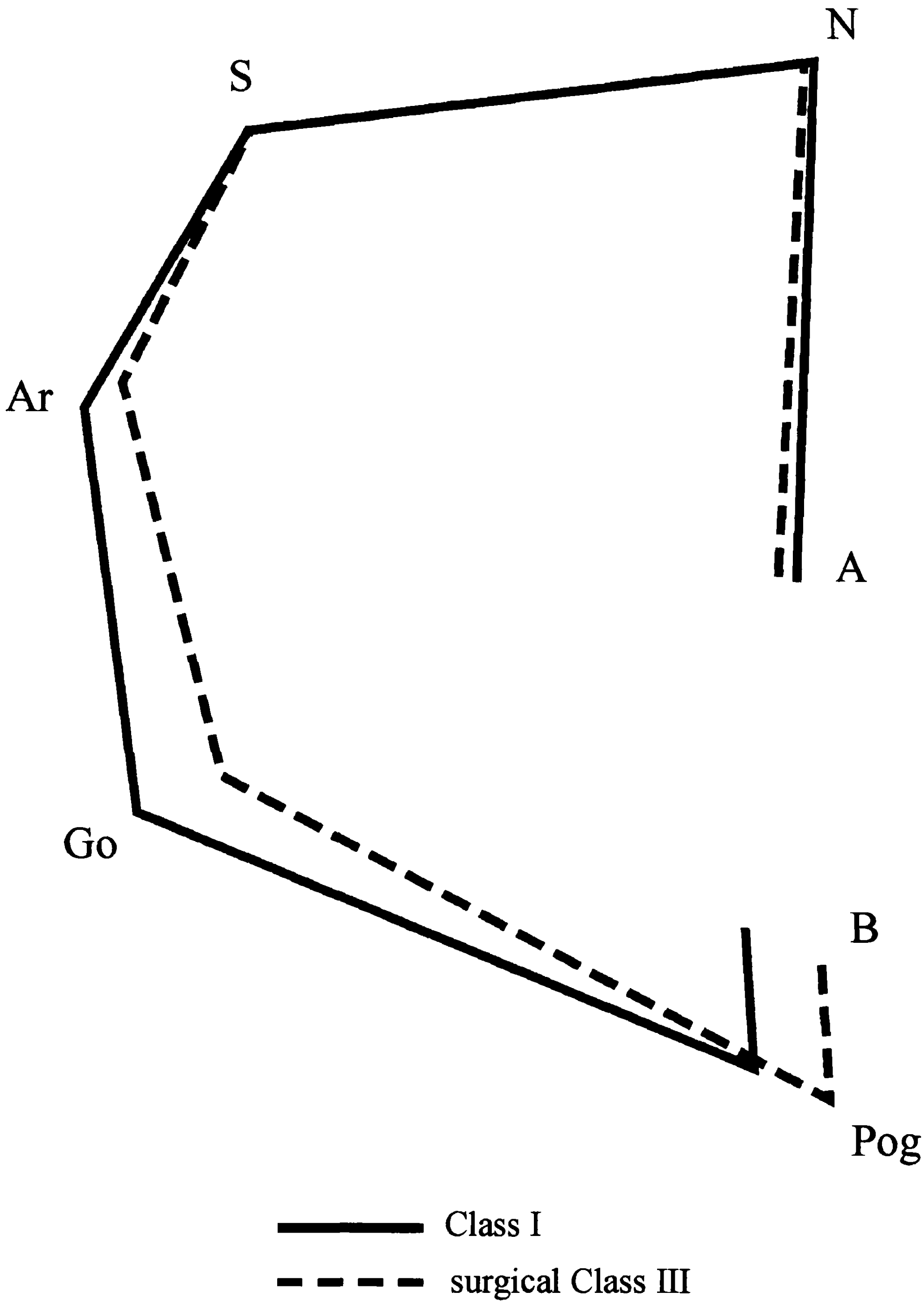

Fig. 5.2. Comparison between representative landmarks of the mean surgical Class III malocclusions and Class I controls.

5.1.3 Discussion

The control sample included in our study is important, and should be compared with other normative data. Therefore, we compared our control data with those reported by Nagaoka and Kuwahara (1993) and Yamanouchi *et al.* (1995) for Japanese individuals with Class I skeletal patterns. Table 5.2 depicts representative cephalometric parameters selected from those of Japanese standard data (the above two studies) and the results of comparison with those examined in our study. Using one-way ANOVA, most parameters were found to be similar, but our control subjects had significantly longer anterior cranial base lengths ($p<0.05$) and more obtuse gonial angles (the Ar-Go-Me angle) ($p<0.01$) compared with the reported control data.

Table 5.2. Comparison of various cephalometric parameters of normal Japanese subjects with Class I reported previously and those of the present control subjects.

	Present control sample N=26		Yamanouchi *et al.* (1995) N=27		Nagaoka and Kuwahara (1993) N=100		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Significance
SNA	81.5	3.0	82.2	2.8	81.4	3.0	NS
SNB	79.0	3.0	80.4	2.9	79.2	3.0	NS
ANB	2.5	0.8	1.8	1.7	2.1	2.1	NS
S-N	70.3	2.7	68.9	2.4	68.7	2.8	*
N-ANS	58.1	2.3	57.3	2.3	57.3	3.0	NS
ANS-Me	72.5	4.2	70.7	5.6	70.1	4.4	NS
Go-Pog	81.1	4.4	79.2	4.3	80.0	4.7	NS
Ar-Go-Me	126.0	6.8	123.2	6.6	121.6	6.0	**

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), and $p<0.01$(**).

The present results suggested that surgical Class III Japanese females had a prognathic mandible. However, there was no significant difference in the mandibular ramus compared with the controls, and the mandibular body length was only approximately 3 mm longer in our test subjects compared with the controls. In fact, the total mandibular length was significantly longer in the test group relative to the controls, but this was due to a more obtuse gonial angle. The effective length of the mandible, from the condyle to chin, was expanded by the obtuse gonial angle; the longer total mandibular length was not the major result of the longer mandibular body in subjects with surgical Class III malocclusion. Thus, patients with skeletal Class III malocclusion do not seem to have a prognathic mandibular body, and the obtuse gonial angle appears to influence the skeletal growth pattern in patients with Class III malocclusion.

Although previous investigators (Sanborn, 1955; Mills, 1966; Susami, 1967; Ahlgren, 1970; Rakosi, 1970; Jacobson *et al.*, 1974; Ellis and McNamara, 1984; Guyer *et al.*, 1986; Williams and Andersen, 1986; Toms, 1989; Chang *et al.*, 1992; Tollaro *et al.*, 1994; Kao *et al.*, 1995) reported that a retrusive maxilla was one of the key findings in skeletal Class III patients, there was no significant difference in the S-N-A angle between the test and control groups in the present study. On the other hand, the linear parameters, S-A and Ar-A, were significantly shorter in the malocclusion group compared with the controls. These results are likely to be related to the position of points S and Ar, and could not simply imply that patients with skeletal Class III malocclusion have a retrusive maxilla. Individuals with surgical Class III malocclusions might have poor maxillary growth, but the antero-posterior position of the maxilla is not a distinct feature of skeletal Class III malocclusion.

Our results showed important differences in cranial base relationships in subjects with surgical Class III abnormality. There was no significant difference in the N-S-Ba angle between the test and control groups, but a smaller N-S-Ar angle was noted in the malocclusion group relative to the control. These results show that the test patients had a normal cranial base angle (the N-S-Ba angle) and a smaller saddle angle (the N-S-Ar angle), which indicates a more anteriorly positioned point Ar. In addition, the shorter S-Ar length in the test sample might be the result of anteriorly positioned TMJ. Previous studies (Sanborn, 1955; Susami, 1967; Horowitz *et al.*, 1969; Dietrich, 1970; Rakosi, 1970; Ridell *et al.*, 1971; Sawa, 1978; Yamazaki and Iwasawa, 1981; Jarvinen, 1984; Guyer *et al.*, 1986; Williams and Andersen, 1986; Yamazaki, 1988; Toms, 1989; Chang *et al.*, 1992; Lu *et al.*, 1993; Tollaro *et al.*, 1994; Dibbets, 1996; Baik *et al.*, 2000; Bandai *et al.*, 2000; Kurokawa *et al.*, 2000) have examined the relationships between cranial base and skeletal disharmonies, but the majority of these studies analyzed N-S-Ba angle or the N-S-Ar angle as a parameter of cranial base angle, which might have produced conflicting conclusions. Yamazaki (1988) examined both N-S-Ba and N-S-Ar angles in Japanese patients with skeletal Class III malocclusion, and reported a normal cranial base angle (the N-S-Ba angle) and a smaller saddle angle (the N-S-Ar angle). The present results are in agreement with those of the above study.

Sekiya *et al.* (1999) compared the craniofacial structures of surgical Class III Japanese females with those of non-surgical Class III sample. They found a more anteriorly positioned point Ar and a more obtuse gonial angle in the surgical group. Interestingly, the antero-posterior position of Ar and the gonial angle were also different between the surgical and non-surgical groups in their study. According to their findings, the saddle angle (the N-S-Ar angle) and gonial angle (the Ar-Go-Me angle) are important parameters for the diagnosis of skeletal Class III malocclusion. The results of the present study are in agreement with those of the above study.

Analysis of the dentoalveolar parameters showed a normal inclination of upper incisors but retroclined lower incisors in the surgical Class III test subjects. These changes probably represent dental compensation for skeletal disharmony. In this regard, Muramatsu *et al.* (1986) demonstrated that the inclination of lower incisors correlated with the severity of Class III skeletal disharmony; the surgical Class III group had more retroclined lower incisors than the controls. The present results support their findings, and suggest that the inclination of lower incisors could be used as an indicator of the severity of Class III skeletal disharmony.

5.1.4 Conclusions

The present study has demonstrated that young adult Japanese females with surgical Class III malocclusion have a smaller saddle angle, which indicates an anteriorly positioned mandible associated with the anteriorly positioned TMJ. The mandibular ramus in these patients is normal, but a longer total mandibular length is a by-product of the obtuse gonial angle. Females with Class III malocclusion have a high-angle facial pattern with longer lower anterior facial height and shorter posterior facial height. With regard to the dentoalveolar components, the test subjects had a normal inclination of the upper incisors and retroclined lower incisors.

Thus, surgical Class III patients do not have an excessively large mandible; the mandible is positioned anteriorly, and the obtuse gonial angle results in a longer mandible. The anteriorly positioned TMJ and more obtuse gonial angle in these individuals were key findings in this study.

5.2 Craniofacial Morphology of Caucasians with Surgical Class III Malocclusions (Study 7)

Although several investigators have examined the craniofacial features of patients with Class III malocclusion (Stapf, 1948; Sanborn, 1955; Maj *et al.*, 1958; Pascoe *et al.*, 1960; Mills, 1966; Horowitz *et al.*, 1969; Ahlgren, 1970; Dietrich, 1970; Rakosi, 1970; Ridell *et al.*, 1971; Jacobson et al., 1974; Ellis and McNamara, 1984; Guyer *et al.*, 1986; Williams and Andersen, 1986; Mackay *et al.*, 1992; Martone *et al.*, 1992; Battagel, 1993; Dibbets, 1996; Tollaro *et al.*, 1996), several different conclusions have been reported in these III studies; for example, Tollaro *et al.* (1994) reported that the length of the mandibular ramus and body were significantly larger in a Class III group, but Jacobson *et al.* (1974) reported that there was no significant difference in the mean ramus heights and corpus lengths between the Class III group and the Class I controls. These conflicting results could have been produced from the different target dentitions and the different definitions of Class III malocclusion; the Angle's Class III molar relationships, an anterior cross bite, and a negative A-N-B angle were often used as criteria of sample selection. Very few investigators have focused on the morphology of surgical Caucasian Class III cases (Ridell *et al.*, 1971; Mackay *et al.*, 1992) which represents the severest Class III growth pattern. Ridell *et al.* (1971) examined 58 adults requiring surgical correction of mandibular protrusion. They summarized that significant differences between normal and the Class III groups were found principally in the mandible; a longer mandibular body length, a normal mandibular ramus height, and a more obtuse gonial angle. Mackay *et al.* (1992) also analysed 50 patients who subsequently underwent surgical correction of Class III malocclusion. They found only 14 % of the subjects had maxillary retrognathia, but an increased lower facial height was found in 58 % of cases. In general, Class III skeletal disharmonies have a relatively high prevalence in Asian countries (Chan, 1974; Ishii *et al.*, 1987; Lew and Foong, 1993; Baik *et al.*, 2000), and a relatively larger number of morphological studies base on surgical Class III cases have been attempted (Yamazaki and Iwasawa, 1981; Motoyoshi *et al.*, 1986; Ngan *et al.*, 1997b; Yamazaki, 1988; Baik *et al.*, 2000).

The purpose of the present study was to further define the morphology of Caucasian surgical Class III malocclusion and compare these features to those of normal Caucasian Class I data.

5.2.1 Material and Methods

5.2.1.1 Subjects

The pre-treatment lateral cephalometric radiographs of 24 British Caucasian females diagnosed with skeletal Class III malocclusion were examined. The sample was randomly selected from the Eastman Dental Hospital, UK, and the mean age was 20.2±3.8 years (range, 15.3-27.4 years). All the Class III sample satisfied the followed criteria: (1) treatment planned for orthognathic surgery, (2) negative A-N-B angle, (3) Angle's Class III molar relationship, and (4) no previous history of any orthodontic treatment. The control data represented the cephalometric standard values of 24 Class I female Caucasian subjects published by Scheideman *et al.* (1980), and the mean age was 24 years (range, 20-32 years).

5.2.1.2 Cephalometric Analysis

All lateral cephalometric radiographs of the surgical Class III sample were taken using the same cephalostat system. The magnifications of the cephalostats were 7.0% and 8.3% for the test and control data respectively; all linear measurements reported in this study were adjusted accordingly. The lateral cephalometric radiograph of each surgical Class III subject was traced by the same investigator. The selected landmarks were digitised and converted to an x-y co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Fig. 5.3). The 12 linear and 10 angular measurements were derived from the parameters used in the Scheideman *et al.*'s study (1980), and these parameters were compared with those of the Class I standards.

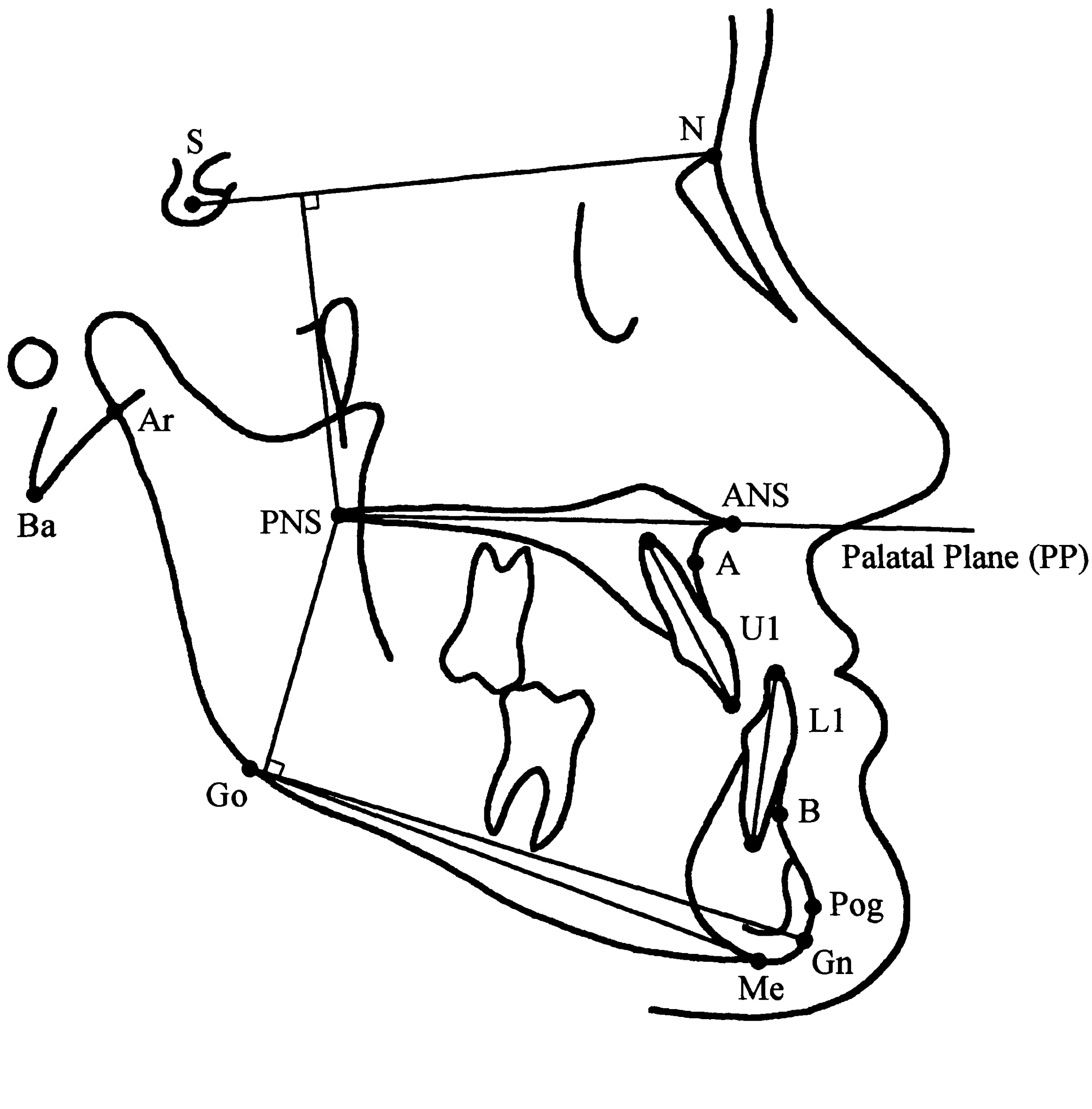

Fig. 5.3. Cephalometric landmarks recorded in Study 7.
- see section 1.2 for definition of landmarks -

5.2.1.3 Error of the Method

24 radiographs of the surgical Class III cases were re-traced and re-digitised 3 weeks later to examine the error of the method. The coefficient of reliability was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 5.3.

5.2.1.4 Statistical Analysis

Standard descriptive statistics, means and standard deviations, of the cephalometric parameters were calculated. Application of parametric tests for all cephalometric variables was justified since parametric tests had the robustness for distribution (Ichihara, 1990). Equality of variance was tested between each of the groups using the F-test, and differences between groups identified using the unpaired Student's and Welch's *t*-test; the former was applied for the parameters which had equal variances, and the later was applied for those which had unequal variances at the F-test.

5.2.2 Results

The coefficient of reliability for all cephalometric parameters satisfied the level of reliability above 0.90 (Houston, 1983). Comparison between the cephalometric measurements of the surgical Class III Caucasian females and the Class I controls is shown in Table 5.3.

5.2.2.1 Cranial Base Relationships

The mean anterior cranial base length (S-N) and total cranial base length (N-Ba) in the surgical Class III group were significantly shorter compared with those of control group ($p<0.01$ and $p<0.05$ respectively), but the posterior cranial base length (S-Ba) was not significantly different between the groups. The cranial base angle was evaluated by the N-S-Ba angle. The mean cranial base angle in the Class I controls was mathematically calculated from the mean values of S-N, S-Ba, and N-Ba. The cranial base angle in the surgical Class III group was shown to be slightly more obtuse compared with the controls.

5.2.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla was evaluated by S-A, the S-N-A angle, and ANS-PNS. According to S-A and the S-N-A angle, the surgical Class III subjects had a significantly more retrusive maxilla compared with the controls ($p<0.01$ and $p<0.05$ respectively). However, there was no significant difference in the size of the maxilla (ANS-PNS) between the groups. The vertical position of the maxilla was evaluated by N-ANS, PNS to S-N, and the angle between the palatal and S-N planes. There was no significant difference in the linear parameters, but the surgical Class III subjects had a significantly larger angle between the palatal and S-N planes compared with the controls ($p<0.05$).

5.2.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by the S-N-B angle and S-Gn. The mandible in the surgical Class III group indicated a significantly protrusive position ($p<0.01$ and $p<0.001$ respectively). The vertical position of the mandible was evaluated by the S-N/Go-Gn angle. The surgical Class III group indicated a significantly larger mandibular plane angle (the S-N/Go-Gn angle) compared with the controls ($p<0.05$). The form of the mandible was examined by Ar-Go, Go-Pog, and the Ar-Go-Me angle. The mean length of the mandibular ramus (Ar-Go) in the surgical Class III sample did not show significant differences compared with Class I control subjects, but the mandibular body (Go-Pog) in the test group was significantly longer compared with the controls ($p<0.05$). The surgical Class III sample also had a significantly more obtuse gonial angle (the Ar-Go-Me angle) compared with the Class I data ($p<0.001$).

5.2.2.4 Intermaxillary Relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A-N-B angle. Not surprisingly, it was significantly smaller in the surgical Class III subjects compared with the controls ($p<0.001$), as this was one of the group selection criteria. The vertical distance between the palatal and mandibular planes was evaluated by ANS-Me, PNS to Go-Me, and the PP/Go-Me angle. The lower anterior facial height (ANS-Me) was significantly longer in the surgical Class III sample compared with the controls, but the lower posterior facial height (PNS to Go-Me) was not significantly different between the groups. The angular parameter (the PP/Go-Me angle) similarly was not significantly different.

5.2.2.5 Dentoalveolar Relationships

The surgical Class III subjects had significantly more proclined upper incisors and retroclined lower incisors compared with the Class I controls ($p<0.05$ and $p<0.001$ respectively).

Table 5.3a. Comparison of mean values between surgical Class III and Class I Caucasian females.

			Present study surgical Class III (N=24)			Scheideman *et al.* (1980) Class I (N=24)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Cranial Base Relationships								
	S-N	(mm)	0.994	65.0	3.2	67.9	3.3	**
	S-Ba	(mm)	0.977	42.0	2.7	42.8	2.6	NS
	N-Ba	(mm)	0.985	97.9	4.2	100.6	4.8	*
	N-S-Ba	(°)	0.978	131.2	5.4	129.2	-	-
Maxillary Skeletal Relationships								
Antero-Posterior	S-A	(mm)	0.987	78.7	3.5	81.8	3.4	**
	S-N-A	(°)	0.986	80.2	4.3	82.6	3.6	*
	ANS-PNS	(mm)	0.974	48.0	2.8	49.0	2.7	NS
Vertical	N-ANS	(mm)	0.984	50.8	3.9	50.0	2.7	NS
	PNS to S-N	(mm)	0.977	42.4	3.0	43.8	2.5	NS
	PP/S-N	(°)	0.938	9.3	3.2	7.0	3.5	*
	L1/Go-Me	(°)	0.996	78.5	5.0	95.6	6.7	***

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***).

Table 5.3b. Comparison of mean values between surgical Class III and Class I Caucasian females.

			Present study surgical Class III (N=24)			Scheideman *et al.* (1980) Class I (N=24)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Mandibular Skeletal Relationships								
Antero-Posterior	S-N-B	(°)	0.991	84.1	5.0	80.1	3.0	**
	S-Gn	(mm)	0.998	124.9	5.0	118.7	4.5	***
Vertical	S-N/Go-Gn	(°)	0.996	34.8	7.5	30.3	4.7	*
Mandible	Ar-Go	(mm)	0.986	45.2	5.0	43.5	4.4	NS
	Go-Pog	(mm)	0.979	77.5	4.8	74.4	3.7	*
	Ar-Go-Me	(°)	0.972	133.9	6.3	126.5	5.0	***

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***).

Red colour: tested by Welch's *t*-test

Table 5.3c. Comparison of mean values between surgical Class III and Class I Caucasian females.

			Present study surgical Class III (N=24)			Scheideman *et al.* (1980) Class I (N=24)		
			coefficient of reliability	Mean	SD	Mean	SD	Significance
Intermaxillary Relationships								
Antero-Posterior	A-N-B	(°)	0.996	-4.0	2.3	2.5	1.8	***
Vertical	ANS-Me	(mm)	0.988	64.1	5.3	62.0	3.1	NS
	PNS to Go-Me	(mm)	0.981	35.7	3.4	38.9	3.7	**
	PP/Go-Me	(°)	0.991	27.5	7.0	25.0	4.2	NS
Dentoalveolar Relationships								
	U1/S-N	(°)	0.995	105.6	5.9	101.7	5.4	*
	L1/Go-Me	(°)	0.996	78.5	5.0	95.6	6.7	***

Significance levels are denoted as: no significant difference(NS), $p<0.05$(*), $p<0.01$(**), and $p<0.001$(***).

5.2.3 Discussion

The published normal Class I cephalometric values obtained from North American Caucasian females was used as a control for British Caucasian female with surgical Class III malocclusion. Although the craniofacial morphology of North American and British Caucasian groups are closer to each other (Trenouth *et al.*, 1985; Trenouth *et al.*, 1999), the present study could have a potential measurement error since the control data was analysed by others. However, the present control values were similar to the other standard values produced from the other investigators (Table 5.4). Thus, the present North American Class I data was considered acceptable as a control group.

Table 5.4. Comparison of various cephalometric parameters of normal Caucasian subjects with Class I occlusions reported previously and those of the present control data.

	Present control data		Riedel (1952)		Steiner (1953)	Bell *et al*. (1980)	
	Mean	SD	Mean	SD	Mean	Mean	SD
S-N-A	82.6	3.6	82.0	3.9	82.0	82.0	4.0
S-N-B	80.1	3.0	80.0	3.7	80.0	79.0	3.0
A-N-B	2.5	1.8	2.0	1.8	2.0	3.0	2.0
S-N/Go-Gn	30.3	4.7	31.7	5.2	32.0	32.0	5.0
U1/S-N	101.7	5.4	104.0	5.8	-	104.0	6.0
L1/Go-Me	95.6	6.7	-	-	-	95.0	7.0

From the present results, it could be concluded that Caucasian surgical Class III females had a retrognathic maxilla and prognathic mandible. However, there was no significant difference in the dimensional parameters of the maxilla and mandible compared with Class I normal data except with regards to the mandibular body length. The form of the mandible was also important as the obtuse gonial angle in the surgical Class III sample in effect increased the total mandibular length. The surgical Class III subjects actually had a posteriorly displaced maxilla and longer total mandibular length caused by the obtuse gonial angle. These two factors combined to produce the severe skeletal disharmony. Ridell *et al.* (1971) in their examination of 58 surgical cases reported similar findings: a longer mandibular body length, a normal mandibular ramus height, and a more obtuse gonial angle. The results of the present study support their findings.

Sekiya *et al.* (1999) compared the craniofacial complex between surgical cases and non-surgical cases with skeletal Class III malocclusion. The authors also found a more obtuse gonial angle in the surgical group. Tahmina *et al.* (2000) examined the craniofacial morphology in Class III patients with stable and unstable treatment outcomes, and they also found a significantly larger gonial angle in the unstable group. Thus, a more obtuse gonial angle could be a distinct indicator of the skeletal Class III growth pattern, and a Class III patient with an obtuse gonial angle might have a potential for severe skeletal disharmony.

In the dentoalveolar components, the surgical Class III sample had more proclined upper and retroclined lower incisors. These findings are indicative of a dental compensation for the underlying skeletal disharmony. In this regard, Muramatsu *et al.* (1986) reported that the inclination of the lower incisors correlated with the severity of Class III skeletal disharmony, and the surgical Class III group had more retroclined lower incisors than the controls. The results of the present study support their findings, and suggest that the dental compensation in the lower arch could reflect the severity of Class III skeletal disharmony.

5.2.4 Conclusions

The craniofacial features of Caucasian surgical Class III malocclusion were as follows: (1) a short cranial base length, (2) a posteriorly positioned but normal sized maxilla, (3) a large total mandibular length associated with an obtuse gonial angle, (4) a high angle facial pattern with shorter posterior facial height, and (5) proclined upper and retroclined lower incisors.

A severe skeletal Class III growth pattern would be produced from the combination of retrusive mid-facial components and an effectively longer mandible associated with obtuse gonial angle, and it could not simply be implied that a severe skeletal Class III patient had a prognathic mandible.

5.3 Craniofacial Differences between Japanese and Caucasians with Surgical Class III Malocclusions (Study 8)

The prevalence of Class III malocclusion varies among races. In the Caucasian population, Haynes (1970) and Foster and Day (1974) screened British girls aged 11-12 years, and noted that 1.6 and 3.2 % of this population had a Class III malocclusion, respectively. On the other hand, Endo (1971) reported that a reversed occlusion was more prevalent (7.81 %) in 11-year-old Japanese girls. Similarly, Susami *et al.* (1971) also reported that the frequency of a reversed occlusion in Japanese females aged between 3 to 19 years was 4.24 %. The higher frequency in the Japanese population was also confirmed in other Asian populations; the prevalence of Class III malocclusions in Chinese and Korean individuals ranges from 9.4 to 19.0 % (Chan, 1974; Baik *et al.*, 2000).

Previous investigators have described the morphological differences between Japanese and Caucasians with respect to Class I (Masaki, 1980; Nezu *et al.*, 1982; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996) and Class II (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Ishii *et al.*, 2001) malocclusions. Although the reported prevalence of Class III malocclusions is different among races, only a few studies have previously examined the morphological differences between Japanese and Caucasians with Class III malocclusions.

Kishi (1991) and Uchiyama (1991) respectively examined differences in the maxillary and mandibular skeletal features between Japanese and Caucasians with Class III malocclusions who required surgical corrections using the same sample. Kishi (1991) reported that Japanese Class III malocclusion is characterized by a reduced cranial base, and more posteriorly positioned maxilla compared with Caucasians, and these features are common in the Japanese population including those with normal and other skeletal disharmonies. Uchiyama (1991) noted that Japanese patients with surgical Class III malocclusion had an increased mandibular ramus and a total mandibular length associated with a more superiorly positioned glenoid fossa compared with Caucasians. Furthermore, that author reported that Japanese Class III patients had a relatively larger mandible compared to the maxilla and thus a more severe skeletal maxilla-mandibular disharmony than Caucasians. However, Uchiyama (1991) did not fully compare the mandibular form and vertical development of the craniofacial structure between the races. Ngan *et al.* (1997b) clarified the cephalometric differences between Chinese and Caucasian patients with surgical Class III malocclusion. They found a reduced anterior cranial base length, a larger posterior cranial base, a smaller gonial angle, and a larger mandible in the Chinese. Similar findings were reported by Singh *et al.* (1998) who examined Class III Korean and Caucasian patients. They noted that Korean Class III patients had a reduced anterior cranial base and midfacial dimensions, and a larger mandible with a smaller gonial angle.

Although there is a lack of information about differences in the vertical development of craniofacial structure between Japanese and Caucasians with Class III skeletal patterns, most previous comparative studies of Japanese and Caucasians with normal and Class II skeletal patterns concluded that the former population has a more excessive vertical development and high-angle facial patterns compared with Caucasian subjects (Masaki, 1980; Nezu *et al.*, 1982; Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996; Ishii *et al.*, 2001). However, other Asian Class III patients have a low-angle facial pattern associated with a smaller gonial angle compared with the Caucasians (Ngan *et al.*, 1997b; Singh *et al.*, 1998). These findings are conflicting, indicating that the craniofacial differences between Japanese and Caucasian patients with skeletal Class III malocclusion are still unclear, especially the racial differences in vertical development and the mandibular form.

The purpose of the present study was to characterize the morphological features of the craniofacial structure of Japanese females with skeletal Class III malocclusions and to compare these features with those of Caucasians with a skeletal Class III malocclusion, with the aim of clarifying the differences in craniofacial morphology between the two races.

5.3.1 Material and Methods

5.3.1.1 Subjects

The pre-treatment lateral cephalometric radiographs of 28 Japanese and 24 British Caucasian females diagnosed with skeletal Class III malocclusions and scheduled for orthognathic surgery were examined. Both groups were randomly selected from the Department of Orthodontics, Matsumoto Dental University, Japan, and Eastman Dental Hospital, UK. All Japanese and Caucasian female patients satisfied the following criteria: (1) treatment planned for orthognathic surgery, (2) negative A-N-B angle, (3) Angle Class III molar relationship, and (4) no previous history of any orthodontic treatment. The mean age was 19.6±3.5 years (range, 15.1-27.1 years) and 20.2±3.8 years (range, 15.3-27.4 years), for the Japanese and Caucasians, respectively.

5.3.1.2 Cephalometric Analysis

All lateral cephalometric radiographs were taken using the same cephalostat system for each group. The image magnification of the cephalostat for the Japanese and Caucasian patients was 10% and 7%, respectively, and all linear measurements reported in this study were adjusted accordingly. All lateral cephalograms of each subject were traced by the same investigator. The selected landmarks were digitised and converted to an x-y coordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Fig. 5.4). The 14 linear and 13 angular measurements represented the original parameters and those derived from the analyses of

Steiner (1953, 1959, 1960) and Jarabak (Jarabak and Fizzell, 1972).

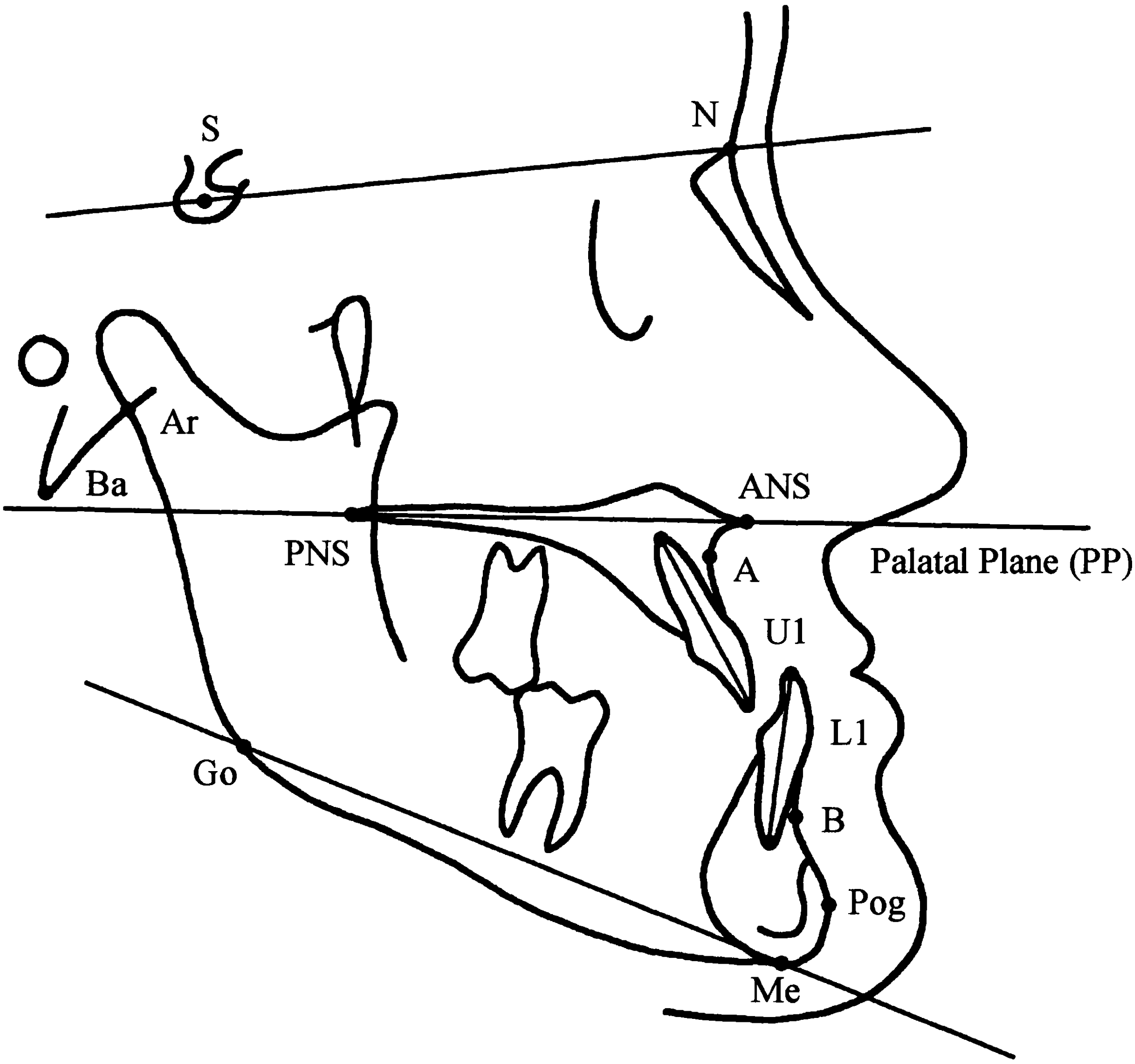

Fig. 5.4. Cephalometric landmarks recorded in Study 8.
- see section 1.2 for definition of landmarks -

5.3.1.3 Error of Measurements

All 52 lateral cephalograms were re-traced and re-digitised 3 weeks after the initial analysis. The error of the method was examined by the coefficient of reliability, calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 5.5.

5.3.1.4 Statistical Analysis

The mean and standard deviation of each parameter were calculated. The D'Agostino-Pearson test was used to determine the distribution of cephalometric variables prior to using parametric tests. Equality of variance was tested between each group by the F-test. The unpaired Student's and Welch's *t*-tests were applied to each parameter to test the significance of differences between groups; the former was applied to parameters that had equal variances, while the latter was applied to those that had unequal variances at the F-test.

5.3.2 Results

All cephalometric parameters were tested by the Student's *t*-test since they had equal variances at the F-test, and the coefficient of reliability for all cephalometric parameters satisfied the level of reliability above 0.90 (Houston, 1983). The results of the comparison between cephalometric measurements of Japanese and Caucasian females with skeletal Class III malocclusion are presented in Table 5.5 and Figure 5.5.

5.3.2.1 Cranial Base Relationships

The mean anterior cranial base length (S-N) was significantly reduced in the Japanese patients compared with the Caucasians ($p<0.01$). However, the other cranial base parameters; posterior cranial base length (S-Ar), total cranial base length (N-Ar), saddle angle (the N-S-Ar angle) and the cranial base angle (the N-S-Ba angle), were not significantly different between the two groups.

5.3.2.2 Maxillary Skeletal Relationships

The anteroposterior position of the maxilla was evaluated by measuring S-A, Ar-A, and the S-N-A angle. Only Ar-A was significantly reduced in the Japanese females compared with the Caucasians ($p<0.05$). S-A and S-N-A angle were not significantly different between the groups. Based on the parameters of vertical development, N-ANS and PP/S-N angle were not significantly different between the groups.

5.3.2.3 Mandibular Skeletal Relationships

The anteroposterior position of the mandible was evaluated by measuring S-B and the S-N-B angle. Although the linear parameter was significantly increased in the Japanese females compared with the Caucasian group ($p<0.05$), there was no significant difference in the angular parameter between the two groups. The anteroposterior position of the chin evaluated by S-Pog and the S-N-Pog angle did not show a significant difference between the Japanese and Caucasian groups. The vertical position of the mandible was evaluated by measuring N-Me, S-Go, S-N/Go-Me angle, and S-Ar-Go angle. The total anterior facial height (N-Me) and the mandibular plane angle (the S-N/Go-Me angle) in the Japanese group were significantly increased compared with the Caucasians ($p<0.05$), but the posterior facial height (S-Go) and the saddle angle (the S-Ar-Go angle) were not significantly different. The form of the mandible was examined by Ar-Go, Go-Pog, Ar-Pog, and the Ar-Go-Me angle. None of the linear measurements of the mandible indicated significant difference between the two groups, but the Japanese females had a significantly more obtuse gonial angle (the Ar-Go-Me angle) compared with the Caucasian patients ($p<0.05$).

5.3.2.4 Intermaxillary Relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A-N-B angle. There was no significant difference between the groups. The vertical distance between the palatal and mandibular planes was examined by ANS-Me and the PP/Go-Me angle. The linear parameter showed a significantly increased lower anterior facial height in the Japanese patients ($p<0.01$), but the angular parameter did not show a significant difference between the two groups.

5.3.2.5 Dentoalveolar Relationships

The Japanese females had significantly more proclined upper incisors compared with the Caucasians ($p<0.01$), but the inclination of lower incisors was similar between the groups.

Table 5.5a. Comparison of mean values between Japanese and Caucasian females with surgical Class III malocclusion.

			Japanese surgical Class III (N=28)			Caucasian surgical Class III (N=24)			
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Significance
Cranial Base Relationships									
	S-N	(mm)	0.992	62.5	3.1	0.994	65.0	3.2	**
	S-Ar	(mm)	0.950	31.4	3.4	0.977	30.3	2.6	NS
	N-Ar	(mm)	0.956	84.1	4.1	0.981	85.8	4.0	NS
	N-S-Ar	(°)	0.974	123.8	5.5	0.969	124.4	5.6	NS
	N-S-Ba	(°)	0.973	131.6	4.8	0.966	131.2	5.5	NS
Maxillary Skeletal Relationships									
Antero-Posterior	S-A	(mm)	0.990	76.8	4.0	0.986	78.7	3.5	NS
	Ar-A	(mm)	0.983	76.3	3.6	0.993	78.7	3.7	*
	S-N-A	(°)	0.987	80.1	4.2	0.986	80.2	4.3	NS
Vertical	N-ANS	(mm)	0.967	51.4	2.6	0.983	50.8	3.9	NS
	PP/S-N	(°)	0.949	10.0	3.5	0.944	9.4	3.3	NS

Significant levels are denoted as: no significant difference(NS), $p<0.05$(*), and $p<0.01$(**).

Table 5.5b. Comparison of mean values between Japanese and Caucasian females with surgical Class III malocclusion.

			Japanese surgical Class III (N=28)			Caucasian surgical Class III (N=24)			
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Significance
Mandibular Skeletal Relationships									
Antero-Posterior	S-B	(mm)	0.989	112.2	5.3	0.984	108.9	4.8	*
	S-N-B	(°)	0.991	84.3	4.7	0.991	84.1	5.0	NS
	S-Pog	(mm)	0.996	125.8	6.4	0.993	122.8	5.0	NS
	S-N-Pog	(°)	0.990	84.3	4.8	0.993	84.7	5.3	NS
Vertical	N-Me	(mm)	0.999	120.3	7.5	0.996	114.6	8.0	*
	S-Go	(mm)	0.945	72.3	4.8	0.991	70.6	4.8	NS
	S-N/Go-Me	(°)	0.996	40.9	6.1	0.996	36.8	7.5	*
	S-Ar-Go	(°)	0.944	139.2	7.3	0.966	138.5	7.0	NS
Mandible	Ar-Go	(mm)	0.939	45.7	4.1	0.986	45.2	5.0	NS
	Go-Pog	(mm)	0.968	76.8	4.8	0.980	77.5	4.8	NS
	Ar-Pog	(mm)	0.996	112.4	5.6	0.992	111.2	4.6	NS
	Ar-Go-Me	(°)	0.968	137.9	7.1	0.972	133.9	6.3	*

Significant levels are denoted as: no significant difference(NS) and $p<0.05$(*).

Table 5.5c. Comparison of mean values between Japanese and Caucasian females with surgical Class III malocclusion.

			Japanese surgical Class III (N=28)			Caucasian surgical Class III (N=24)			
			coefficient of reliability	Mean	SD	coefficient of reliability	Mean	SD	Significance
Intermaxillary Relationships									
Antero-Posterior	A-N-B	(°)	0.993	-4.2	2.4	0.996	-4.0	2.3	NS
Vertical	ANS-Me	(mm)	0.996	69.2	6.5	0.989	64.1	5.3	**
	PP/Go-Me	(°)	0.989	30.8	6.4	0.989	27.4	7.0	NS
Dentoalveolar Relationships									
	U1/S-N	(°)	0.997	110.3	6.6	0.995	105.6	5.9	**
	L1/Go-Me	(°)	0.999	75.0	7.4	0.996	78.5	5.0	NS

Significant levels are denoted as: no significant difference(NS) and $p<0.01$(**).

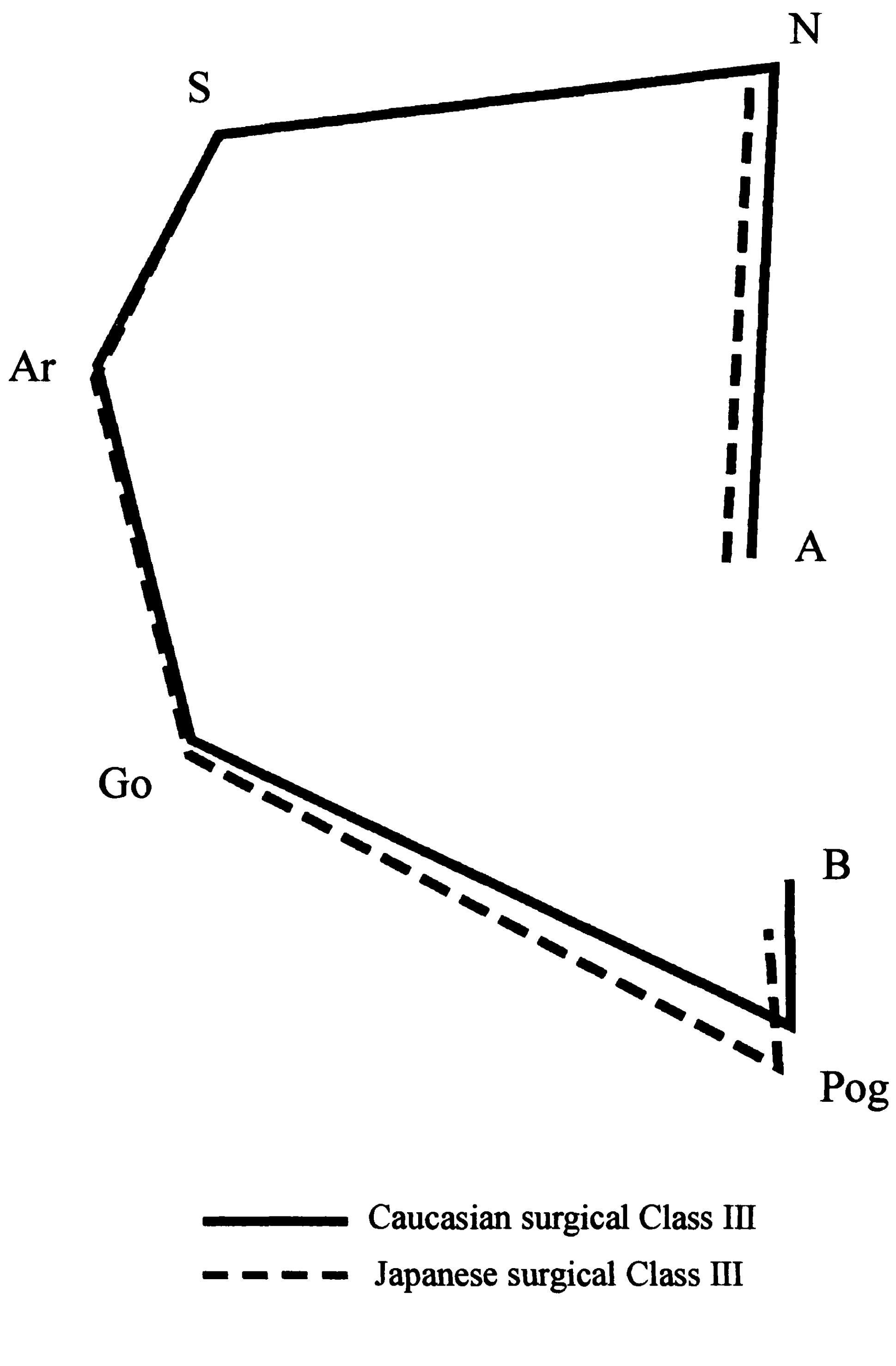

Fig. 5.5. Comparison between representative landmarks of the mean Japanese and Caucasian sample with surgical Class III malocclusions.

5.3.3 Discussion

The major finding of the present study was the reduced anterior cranial base length in the Japanese females with skeletal Class III malocclusion compared with their Caucasian counterparts. In general, the majority of previous investigations that compared the craniofacial morphology between Asians and Caucasians reported that Asians had a reduced anterior cranial base length not only in those with a Class I occlusion (Masaki, 1980; Nezu *et al.*, 1982; Cooke and Wei, 1989; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996), but also in subjects with Class II (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Ishii *et al.*, 2001) and Class III (Kishi, 1991; Ngan *et al.*, 1997b; Singh *et al.*, 1998) malocclusions. Fukui *et al.* (1992) examined the morphological features of the maxilla and cranial base in Taiwanese with pseudo anterior cross-bite, and compared their findings with those of Japanese and American Whites. The maxilla and the dento-alveolar component of Taiwanese were slightly different from those of Japanese, but the form of the cranial base was similar in both races. They stated that the development of the maxilla and the dento-alveolar component might be influenced by their oral functions, but the form of the cranial base could directly reflect the genetic characteristics. The present study characterised the typical racial differences in craniofacial morphology among Asian and Caucasian populations.

With respect to the mandibular dimensions, there was no significant difference between the Japanese and Caucasian groups; the mandible was similar in size in both groups. However, the cranial base and midfacial component of the Japanese patients were much more reduced compared with the Caucasian group. Reduced midfacial dimension has been found in previous studies of Class III patients (Kishi, 1991; Ngan *et al.*, 1997b; Singh *et al.*, 1998). These results indicate that Asian skeletal Class III patients have a relatively larger mandible compared with the cranial base and maxilla. Uchiyama (1991) reported similar findings, and concluded that the more severe skeletal abnormalities were less favourable with regard to orthodontic and orthognathic treatments of Japanese and other Asian populations.

A steeper mandibular plane angle (the S-N/Go-Me angle) associated with a more obtuse gonial angle (the Ar-Go-Me angle) was also found in the Japanese females with skeletal Class III malocclusions compared with Caucasians in the present study. These results are in conflict with the findings of Ngan *et al.* (1997b) and Singh *et al.* (1998) who respectively compared skeletal Class III Chinese and Korean with Caucasians: both investigators reported that Chinese/Korean had a smaller mandibular plane angle and gonial angle. From this point of view, the morphological features of the craniofacial structure of Japanese Class III patients seems to be different from the Chinese and Korean patients although all three races are categorised into Mongoloid. The results of Chui and Kawamoto (1990) could support this assumption. They compared Chinese children with a Class III malocclusion with Japanese subjects. They stated that both races had similar skeletal features, but Chinese subjects had a significantly smaller mandibular plane angle compared with the Japanese. Thus, Japanese Class III patients have more excessive vertical development associated with a larger mandibular plane angle and gonial angle compared with Caucasian Class III patients, and this racial feature is supported by the comparative studies between Japanese and Caucasian Class I (Masaki, 1980; Nezu *et al.*, 1982; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996) and Class II (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Ishii *et al.*, 2001) subjects.

The Japanese females in the present study had a reduced anterior cranial base length, a more retrusive midfacial component, and a high-angle facial pattern with steeper mandibular plane compared with the Caucasians. In general, these differences between Japanese and Caucasians with surgical Class III were not specific to the skeletal Class III growth pattern; they would seem to be common racial differences. However, these common racial features in the Japanese would not be favourable for the Class III skeletal pattern, as the retrusive midfacial component indicated a more posteriorly positioned maxilla, whilst a steeper mandibular plane made the effective mandibular length more increased. In other words, Japanese individuals tend to have a more retrognathic maxilla and prognathic mandible compared with Caucasians. These common skeletal features based on racial differences might be less favourable for correction of the Class III skeletal pattern.

5.3.4 Conclusions

The results of this study showed that the major craniofacial differences between Japanese and Caucasian females with skeletal Class III malocclusion were as follows. Japanese females had (1) a significantly reduced anterior cranial base length, (2) a significantly more obtuse gonial angle, (3) a high-angle facial pattern with a significantly increased lower anterior facial height, and (4) significantly more proclined upper incisors. These differences in subjects with skeletal Class III malocclusion might represent common differences in skeletal features between the two racial groups, but the reduced mid-facial component and high-angle facial pattern in Japanese population would be less favourable for correcton of a Class III skeletal pattern compared with Caucasians.

CHAPTER 6

Overall Conclusions

6.1 Conclusions

Cephalometric analyses have been widely used as a tool for studying craniofacial development, and it has been the most frequently applied quantative technique within orthodontic research. It has been the only method that permits the investigation of the spatial relationships between cranial structures and between dental and surface structures. However, a high possibility of measurement error has been reported since it is physically impossible to locate the positions of anatomical structures accurately even in two dimensions in the absence of information about the third dimension. In addition, it can be very difficult to acquire structural information from the cephalograms which have a lack of hard edges, shadows, and well-defined outlines.

Unfavourable factors of cephalometric analyses should be minimized; image quality and appropriate landmark choice must be very important. In this research, a computer-aided cephalometric image manipulation system was examined. The method was divided into two stages: making an intentionally dull contrast image, and expanding the colour range into full 8-bit, 256 greyscale colours. From the result of the manipulation, significantly more distinct target edges with larger colour level differences in adjoining areas were found in the manipulated images. The logical computer-aided image manipulation method was effective for cephalometric research purposes.

Although a numbers of investigators have attempted to demonstrate the craniofacial structures of different populations, comparative studies between different races are less common. This is especially true with regard to the racial differences in the craniofacial structure both in normal occlusion and malocclusions. It is very important when considering orthodontic treatments to fully understand the skeletal differences between races as treatment methods designed for one race, may not necessarily be applicable to another.

In this research, morphological differences in the craniofacial structure between Japanese and Caucasian were examined using lateral cephalograms. The morphological comparisons were divided into three sections: Class I normal occlusion, Class II malocclusion, and Class III malocclusion. For the Class II and Class III sections, the malocclusion cases were also compared with the normals in each race.

In the comparison between Japanese and Caucasians with normal Class I occlusion, the Japanese sample had significantly shorter anterior and posterior cranial base lengths, longer anterior and posterior facial heights, and more proclined upper incisors compared to the Caucasians. These skeletal features indicated that the normal Japanese sample had a brachycephalic cranium and a dolichocephalic mandible.

In the Class II studies, the Japanese Class II patients had a significantly shorter mandibular ramus, a retrognathic mandible, and a high-angle facial pattern compared with the normals. The key finding in the Class II Japanese patients was a shorter mandibular ramus associated with a high-angle facial pattern and the retrognathic mandible.

The growth pattern of untreated skeletal Class II patients was also examined using Japanese subjects. Untreated Japanese girls with skeletal Class II malocclusion had a similar growth pattern in the cranial base and similar vertical development compared to Class I controls. A protrusive maxilla was seen in the early phase, a retrognathic mandible in the later phase, and less anterior growth of both the maxilla and the mandible during the mixed dentition compared to the Class I controls. The results suggested that the Class II skeletal growth pattern started with maxillary protrusion which settled to a normal anteroposterior position during growth, but the retrusive mandible remained in the later phase of the mixed dentition.

The Caucasian Class II patients had different skeletal features. The Caucasian Class II patients had an obtuse cranial base angle and a posteriorly positioned mandible associated with the posteriorly positioned glenoid fossa compared with the normals.

In the racial comparison between Japanese and Caucasians with Class II malocclusions, the Japanese had a significantly shorter anterior cranial base length, a more obtuse articular angle, a steeper mandibular plane angle, and more proclined lower incisors compared to the Caucasians. The backward rotation of the mandible associated with Japanese and the anterior positioned maxilla in Caucasians could be the main reasons for the intermaxillary disharmony.

From the results of the Class III comparisons, the surgical Class III Japanese had a significantly smaller saddle angle, a longer total mandibular length associated with an obtuse gonial angle, and a high-angle facial pattern compared to the normals. The anteriorly positioned mandible and obtuse gonial angle in these individuals were key findings.

In Caucasian populations, the surgical Class III Caucasians had a significantly shorter cranial base length, a posteriorly positioned but normal size maxilla, a longer total mandibular length associated with an obtuse gonial angle, and a high-angle facial pattern compared to the normals. The severe skeletal Class III growth pattern could arise from the combination of retrusive mid-facial components and an effectively longer mandible associated with obtuse gonial angle.

In the racial comparisons between Japanese and Caucasians with surgical Class III malocclusion, the Japanese sample had a reduced anterior cranial base length, a longer anterior facial height, a more obtuse gonial angle, and more proclined upper incisors compared to the Caucasians. These differences in subjects with surgical Class III malocclusion were similar to those in Class I and II skeletal patterns, and no specific racial difference was found in the surgical Class III skeletal pattern.

On the whole, the Japanese population had different skeletal features compared to the Caucasians both in normal occlusion and malocclusions. A brachycephalic cranium and a dolichocephalic mandible associated with a shorter cranial base and excessive vertical development could be common racial features in the Japanese population. In addition, both in the Class II and Class III malocclusions, the Japanese patients had more excessive vertical development, whilst the Caucasian patients had more excessive horizontal development. It is apparent therefore that the Japanese patients tend to have more vertical problems, whereas the Caucasian patients tend to have horizontal problems in the skeletal disharmonies.

In today's world, orthodontists are faced with treating a whole range of malocclusions presenting in different racial groups. If treatment is to be successful, it is important to understand both the morphological and cultural differences between the races. This study has formed a basis for understanding the different approaches to treatment that are likely to be required when treating Japanese and Caucasian patients.

CHAPTER 7

Suggestions for Future Work

7.1 Future Work

A computer-aided cephalometric image manipulation method was used in the present study, but the enhanced method was not compared with the standard approach. It would therefore be useful to undertake a comparison study of the two methods using the material from this investigation. The craniofacial structure of the non-treated Japanese and Caucasians has been examined in the present study. On the basis of the findings, it would be appropriate to compare the response between the racial groups to various orthodontic treatment modalities. One example of this could be to study the response to various designs of functional appliance, especially those aimed at achieving either a predominently vertical as opposed to a horizontal correction. The findings of the present study could then provide the control data. A prospective randomised multi-centre trial using the same functional appliance for different racial groups would be ideal for examination of racial differences in clinical response.

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Craniofacial Morphology of Japanese Girls with Class II Division 1 Malocclusion

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Abstract

Objective: *To identify the craniofacial features of Japanese girls with Class II division 1 malocclusions.*

Method: *One hundred and ninety lateral cephalometric radiographs were analysed, and the subjects whose age ranged from 7 years 6 months to 15 years 10 months were divided into three groups by their dentition: middle mixed dentition, late mixed dentition, and early permanent dentition. The mean values of 5 linear and 16 angular cephalometric parameters were compared with established Japanese Class I control values.*

Results: *Japanese girls with Class II division 1 malocclusion had a significantly small S-N-B angle ($p < 0{\cdot}001$), short mandibular ramus ($p < 0{\cdot}05$–$0{\cdot}001$), and a large mandibular plane angle ($p < 0{\cdot}05$–$0{\cdot}001$).*

Conclusion: *Japanese girls with Class II division 1 malocclusion had a high-angle facial pattern associated with the short mandibular ramus.*

Index words: Angle Class II Malocclusion, Computer-aided Cephalogram, Japanese Adolescents, Skeletal Class II.

Introduction

Analysis of craniofacial structures using lateral cephalometric radiographs has been used for the prediction of growth, as well as diagnosis and treatment planning in orthodontics for many years. A Class II skeletal pattern with maxillary protrusion and mandibular retrusion, positionally and morphologically, is a frequent dentofacial abnormality in American and European whites (Haynes, 1970; Proffit *et al.*, 1998), Chinese (Lew *et al.*, 1993), and Japanese (Susami *et al.*, 1971; Kitai *et al.*, 1990). Many studies have attempted to clarify the morphological features of skeletal Class II malocclusion, and most investigators have reported the presence of a retrognathic mandible, proclined upper incisors, and neutral positioned lower incisors in Caucasian (Drelich, 1948; Renfroe, 1948; Henry, 1957; Harris *et al.*, 1972; Hitchcock, 1973; McNamara, 1981), Chinese (Lau and Hagg, 1999), and Japanese Class II patients (Miura *et al.*, 1958; Kuwahara, 1968; Iwasawa *et al.*, 1969, 1980). However, investigations of the antero-posterior position of the maxilla and the size of the mandible in Class II subjects have not reported consistent results. Furthermore, the skeletal Class II pattern arises from not only horizontal, but also vertical discrepancies (Adams and Kerr, 1981), aided by the morphology of the cranial base (Bacon *et al.*, 1992). The influence of these morphological features has not been fully evaluated for a Japanese population. As a result, the purpose of the present study was to further define the morphology of Japanese skeletal Class II malocclusion and compare these features to those of normal Japanese Class I data.

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Material and Methods

One-hundred-and-ninety lateral cephalometric radiographs of Japanese girls with Class II division 1 malocclusion and who had no history of any orthodontic treatment were examined. All patients had an A–N–B angle > 5 degrees, an Angle's Class II molar relationship, and an increased overjet. The control data represented the cephalometric standard values of Class I Japanese children published by the Japanese Society of Paediatric Dentistry in 1995 (JSPD). The Class II sample were divided into three groups based on dental age:

1. Middle mixed dentition, in which the upper and lower central and lateral incisors had erupted fully, but the deciduous canines and molars were still present.
2. Late mixed dentition, in which the permanent canines and premolars were erupting.
3. Early permanent dentition, in which all deciduous teeth had been shed and the second molars were at least partially erupted.

The mean age of each group is shown in Table 1.

Cephalometric Analysis

All lateral cephalometric radiographs of the Class II sample were taken using the same cephalostat system, and both the

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test and control data had the same image magnification (10·0 per cent enlargement). The lateral cephalometric radiograph of each subject was traced by the same investigator. The selected landmarks were digitized and converted to an *x–y* co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan; Figure 1). In this study, points Po and Or were not used since poor reproducibility has been reported previously (Cooke and Wei, 1991). From these, five linear and 16 angular measurements were compared with those of the Class I standards.

Error of the Method

Fifty radiographs were re-traced and re-digitized a few weeks later to examine the error of the method. The coefficient of reliability was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$, where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 2.

Statistical Analysis

Standard descriptive statistics, means and standard deviations, of age and cephalometric parameters were calculated for each group. The chi-square test was applied to all cephalometric parameters to test for normal distribution. Equality of variance was tested between each of the groups and differences between groups identified using the unpaired Student's and Welch's *t*-test.

TABLE 1 *Distribution of Class II division 1 and Class I Japanese females*

Present study						Japanese Society of Pediatric Dentistry (1995)					
Class II division 1 Japanese females						Class I Japanese females					
Group 1 (n = 76)		Group 2 (n = 55)		Group 3 (n = 59)		Group I (n = 24)		Group 2 (n = 29)		Group 3 (n = 36)	
7 y 6 m–11 y 0 m		9 y 1 m–13 y 6 m		10 y 9 m–15 y 10 m		7 y 7 m–11 y 7 m		8 y 0 m–12 y 1 m		10 y 10 m–16 y 10 m	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
8 y 6 m	9·9	10 y 11 m	9·3	13 y 0 m	18·9	9 y 1 m	11·0	10 y 8 m	10·8	13 y 2 m	15·7

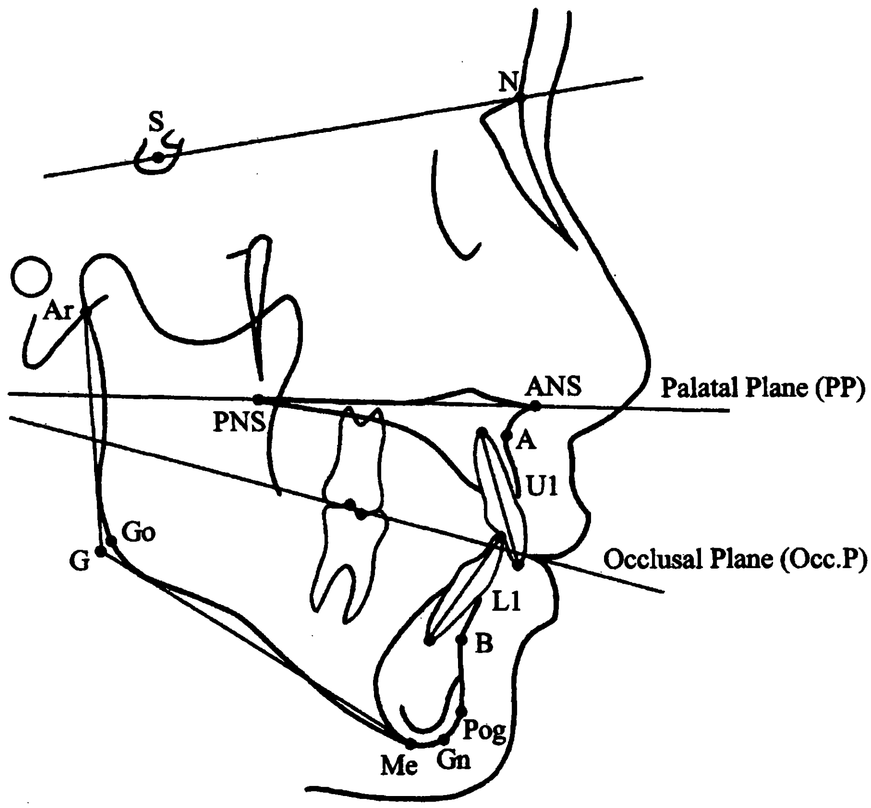

FIG. 1 Cephalometric landmarks recorded in this study.

TABLE 2 *Comparison of mean values between Class II division 1 and Class I Japanese females*

			Present study						JSPD (1995)					
			Class II division 1						Class I					
			Group 1 (n = 76)		Group 2 (n = 55)		Group 3 (n = 59)		Group 1 (n = 24)		Group 2 (n = 29)		Group 3 (n = 36)	
		Coefficient of reliability	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cranial base relationships														
	S–N	0·957	65·3	2·7	66·9	2·6	67·8***	2·3	65·8	2·7	67·8	3·1	69·6***	2·6
	S–Ar	0·974	32·7	2·7	34·7	2·8	35·9	2·8	—	—	—	—	—	—
	N–S–Ar	0.978	127.3	4.4	127.2	4.4	127.2	4.7	—	—	—	—	—	—
Maxillary skeletal relationships														
Antero-posterior	Ar–A	0.991	82.2	3.3	85.0	3.9	86.8	4.0	—	—	—	—	—	—
	S–N–A	0.942	81.5	3.2	81.8**	2.9	82.0**	3.3	80.2	3.2	79.7**	3.0	80.1**	2.5
Vertical	N–ANS	0.950	50.5	3.0	53.2	2.9	55.9	3.0	—	—	—	—	—	— —
	PP/S–N	0.903	9.3	3.0	8.8	2.9	9.9	3.0	9.1	2.7	9.6	2.7	10.1	3.1
Mandibular skeletal relationships														
Antero-posterior	S–N–B	0.953	74.2**	2.9	75.5	3.0	75.7**	3.3	76.3**	2.9	76.3	3.1	77.6**	2.2
	S–N–Pog	0.965	73.6**	2.9	74.9	3.0	74.9***	3.3	75.4**	2.7	75.6	2.8	77.4***	2.7
Vertical	N–Me	0.990	112.1	4.4	118.5	5.9	123.7	6.9	113.1	5.0	116.8	4.6	122.8	6.2
	S–Me	0.995	108.2**	4.1	115.5	5.2	120.3*	6.3	111.0**	5.2	115.4	4.4	123.2*	5.6
	S–N/Ar–G	0.922	93.1	4.6	93.9	4.9	94.4	5.7	94.1	3.8	93.5	3.9	92.7	4.4
	S–N/G–Me	0.986	39.9	4.8	39.6*	5.2	40.4***	6.3	37.8	4.5	36.9*	4.7	36.1***	4.6
	S–Ar–Go	0.957	143.5	5.3	144.2	5.5	144.7	6.1	—	—	—	—	—	—
	Y–Axis	0.962	73.5*	2.8	73.5*	3.3	74.3***	3.6	72.1*	2.5	71.9*	2.7	71.1***	2.7
	N–Ar/S–Gn	0.980	90.5**	2.7	90.9**	3.2	92.0***	3.7	88.7**	3.5	88.6**	2.9	88.0***	2.2
	N–Pog/G–Me	0.987	66.5	3.5	65.5*	3.8	64.7*	5.2	66.8	4.1	67.5*	4.6	66.6*	3.7
Mandible	Ar–G	0.979	39.2***	2.7	41.7*	4.0	43.9***	4.3	42.0***	2.9	43.9*	3.6	47.0***	3.3
	Go–Pog	0.978	68.1	3.9	72.3	4.2	74.2	4.1	—	—	—	—	—	—
	Go–Me	0.969	62.1	3.9	66.6	4.1	68.4***	3.8	63.9	4.2	67.0	2.6	72.4***	4.4
	Ar–Pog	0.996	95.0	3.6	100.6	4.6	104.3	5.4	—	—	—	—	—	—
	Ar–G–Me	0.983	126.8**	6.4	125.7	5.9	126.0	7.9	123.7**	6.6	123.4	5.4	123.4	5.9
Intermaxilliary relationships														
Antero-posterior	A–N–B	0.924	7.3***	1.4	6.3***	1.0	6.3***	1.2	3.8***	1.5	3.3***	1.3	2.6***	1.7
	A–B/N–Pog	0.881	9.7***	2.0	8.4***	1.7	8.4***	1.8	5.2***	2.3	5.0***	2.9	4.1***	2.6
Vertical	ANS–Me	0.989	64.9	3.7	68.2	4.7	70.9	5.6	—	—	—	—	—	—
	PP/G–Me	0.989	30.5	5.1	30.8	5.3	30.3	5.9	—	—	—	—	—	—
Dentoalveolar relationships														
	U1/S–N	0.982	104.7	6.3	106.8	6.3	108.2	6.3	104.9	5.0	105.5	7.0	106.0	4.7
	L1/G–Me	0.972	97.8	5.2	97.8	5.4	99.3*	7.5	97.6	6.2	99.1	5.1	96.4*	5.1
	U1/L1	0.990	117.6	8.1	115.8	7.5	112.1***	9.1	119.7	6.9	118.5	9.9	121.5***	6.9
	Occ.P/S–N	0.847	22.4	3.4	20.5	3.9	20.3	3.9	22.8	2.9	21.3	3.1	19.8	3.3

The symbols mean the significant level: *$P < 0·05$; **$P < 0·01$; ***$P < 0·001$.

Results

The coefficient of reliability for almost all cephalometric parameters satisfied the level of confidence (>0·90). However, two results, A–B/N–Pog angle and Occ.P/S–N angle, had a low coefficient of reliability (<0·90); these should be viewed with caution (Houston, 1983).

Comparison between the cephalometric measurements of the Class II division 1 Japanese girls and Class I controls are shown in Table 2.

The results may be summarized as follows:

Cranial Base Relationships

Although the mean anterior cranial base length (S–N) tended to be shorter in subjects with Class II division 1 malocclusions, this was significantly different only at the early permanent dentition stage.

Maxillary Skeletal Relationship

The anteroposterior position of the maxilla evaluated by the S–N–A angle showed a significantly more protrusive maxilla in Class II division 1 female subjects compared with the control. According to the angle between the palatal and S–N plane, the maxilla was positioned approximately at the same vertical position in both the test and control groups.

Mandibular Skeletal Relationship

The anteroposterior position of the mandible was evaluated by the S–N–B and S–N–Pog angles. The mandible in the Class II division 1 group indicated a significant retrusive position. The vertical position of the mandible was evaluated by two linear parameters (N–Me, S–Me) and five angles (S–N/Ar–G, S–N/G–Me, *y*-axis, N–Ar/S–G, and N–Pog/G–Me). The anterior facial height (N–Me) showed no significant difference in the test and control groups, but S–Me in Class II division 1 group indicated a significant excessive vertical development. It was evident that the following angular measurements showed a significantly excessive vertical development in the Class II sample: S–N/G–Me angle, *y*-axis, N–Ar/S–Gn angle, and N–Pog/G–Me angle. In contrast, the test and control subjects had a similar S–N/Ar–G angle. The mean length of the mandibular ramus (Ar–G) was significantly shorter in the Class II division 1 sample, but the mandibular body length (Go–Me) was not significantly different from the control, except for Group 3. Subjects with Class II malocclusion also had a similar gonial angle (Ar–G–Me angle), except for Group 1.

Intermaxillary Relationship

The anteroposterior relationship between the maxilla and mandible was evaluated by the A–N–B angle and the A–B/N–Pog angle. All were significantly larger in the Class II subjects compared with the controls.

Dentoalveolar Relationship

These were similar in the Class II division 1 and Class I groups except at the early permanent dentition, where the lower incisors were more proclined. Otherwise, the inclination of both upper and lower incisors, and the occlusal plane inclination were similar in both groups.

Discussion

Our study revealed that Class II Division 1 subjects had on average an anteriorly positioned maxilla when compared to JSPD normal controls. When we considered the mandible our results showed a significant retrognathia in the Class II sample according to the S–N–B angle and a shorter mandibular ramus. This agrees with Menezes (1974), who noted that all mandibular dimensions, overall mandibular length, mandibular body length, and vertical ramus were significantly shorter in Class II division 1 subjects. Other investigators have also reported the presence of a short mandibular body length (Nelson and Higley, 1948; Craig, 1951; Henry, 1957). However, in these Caucasian studies, there was no significant difference in the mandibular ramus length between Class II and I. These data indicated that the short mandibular ramus is one of the distinctive features of Japanese female subjects with Class II division 1 malocclusion, and the short posterior facial height (Ar–G) in the present study is the cause of the dolichofacial pattern. Furthermore, the retrusive mandible may be explained by the short mandibular ramus, slightly short mandibular body, and the obtuse gonial angle associated with backward rotation of the mandible.

Conclusions

The characteristic features of Japanese Class II division 1 malocclusion are as follows:

1. Slightly obtuse cranial base angle.
2. Relatively anterior positioned maxilla.
3. Significantly short mandibular ramus.
4. Retrognathic mandible.
5. Slightly obtuse gonial angle.
6. High-angle facial pattern
7. Relatively short posterior facial height associated with a short mandibular ramus.

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Morphological differences in the craniofacial structure between Japanese and Caucasian girls with Class II division 1 malocclusions

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SUMMARY The craniofacial features of 49 Japanese and 75 British Caucasian girls with Class II division 1 malocclusions were evaluated from lateral cephalometric radiographs, and the morphological differences between both races were examined. The subjects' ages ranged from 11 years 1 month to 12 years 11 months. The mean values of 13 linear and 13 angular cephalometric parameters were compared.

The Japanese Class II division 1 sample had a significantly shorter anterior cranial base length (S–N; $P < 0.001$) and a more obtuse articular angle (S–Ar–Go; $P < 0.001$). Analysis of the dentoalveolar components in Japanese subjects showed more proclined lower incisors (L1/Go–Me; $P < 0.05$) and a steeper occlusal plane (Occ.P/S–N; $P < 0.01$) relative to those of Caucasians. The short anterior cranial base length and excessive vertical development in the Japanese population might be common racial morphological features, but the main reason for the Class II division 1 skeletal disharmony in both races was different; it was caused by the anteriorly positioned maxilla in Caucasians and the backward rotated mandible in the Japanese.

Introduction

Although many investigators have attempted to clarify the morphological features of Japanese and Caucasian Class II division 1 patients (Table 1), there are few previous studies that have examined the morphological differences in the craniofacial structure between Japanese and Caucasian patients with Class II division 1 malocclusions (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989). Ono *et al.* (1986) reported that both the maxilla and mandible of Japanese were located more posteriorly than those of Americans, with the Japanese exhibiting greater vertical development. Yamaki (1987) noted that Japanese Class II division 1 patients had a relatively shorter and more posterior positioned maxilla, and greater backward rotation of the mandible compared with Caucasian Class II division 1 patients, and stated that the differences in the maxillary region between Japanese and Caucasians with Class II division 1 malocclusions were common racial differences, and not specific to Class II division 1 malocclusions. Ishizuka *et al.* (1989) reported that Japanese Class II division 1 patients had a significantly shorter anterior cranial base and maxilla, and evidently more backward rotation of the mandible compared with Caucasians. Despite these investigations, there is still a lack of information regarding the morphological differences between Japanese and Caucasians with Class II division 1 malocclusions.

The purpose of this study was to further define the morphology of Japanese Class II division 1 malocclusion, to compare in features with those

Table 1 Previous morphological studies of Class II malocclusions.

Japanese		Caucasians	
		Drelich	1948
		Nelson and Higley	1948
		Renfroe	1948
		Gilmore	1950
		Craig	1951
		Riedel	1952
		Altemus	1955
		Henry	1957
		Blair	1954
Miura *et al.*	1958		
Kuwahara	1968		
Iwasawa *et al.*	1969		
		Rothstein	1971
		Harris *et al.*	1972
		Hitchcock	1973
		Konfino	1973
		Menezes	1974
Iwasawa *et al.*	1980	Moyers *et al.*	1980
		Adams and Kerr	1981
		McNamara	1981
		Anderson and Popovich	1983
		Järvinen	1984
		Siriwat and Jarabak	1985
Tokuda	1987	Carter	1987
		Bacon *et al.*	1992
		Karlsen	1994
Kasai *et al.*	1995	Rosenblum	1995
		Dibbets	1996
		Baccetti *et al.*	1997
		Pancherz *et al.*	1997

of a Caucasian Class II division 1 sample and to elucidate the differences in craniofacial morphology between both races.

Material and methods

The Japanese and Caucasian cephalometric radiographs were selected at random from a private orthodontic practice in Himeji, Japan, and the Eastman Dental Hospital, London, UK, respectively. As a consequence, the lateral cephalometric radiographs of 49 Japanese and 75 Caucasian girls with Class II division 1 malocclusions with no history of orthodontic treatment were examined. All Japanese and Caucasian subjects had an ANB angle >5 degrees on an Angle Class II molar relationship and increased overjet. The mean age of each group is shown in Table 2.

Table 2 Age distribution of the Japanese and Caucasian female sample in this study.

Japanese Class II division 1		Caucasian Class II division 1	
$n = 49$		$n = 75$	
Mean	SD	Mean	SD
11 years 8 months	6.9	11 years 11 months	6.2

Cephalometric analysis

For each group, all lateral cephalometric radiographs were taken using the same cephalostats. The Japanese and Caucasian radiographs had an image magnification of 10 and 7 per cent, respectively. All linear measurements reported in this study were adjusted accordingly. The lateral cephalometric radiographs of each subject were traced by the same investigator. The selected landmarks were digitized and converted to an x–y co-ordinate system (WinCeph, Rise Corporation, Sendai, Japan; Figure 1). In this study, points Po and Or were not used since poor reproducibility has been previously reported (Cooke and Wei, 1991). The 13 linear and 13 angular measurements mostly derived from the

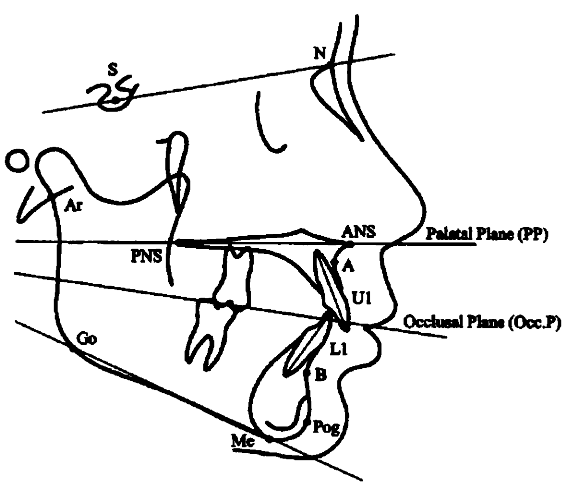

Figure 1 Cephalometric landmarks used in this study.

analyses of Steiner (1953, 1959, 1960) and Jarabak (Jarabak and Fizzell, 1972) were used in this study.

Error of the method

All 124 lateral head films were traced twice. The second tracing was carried out a few weeks later. The error of the method was determined using the coefficient of reliability, which was calculated for each measurement as follows: coefficient of reliability = $1 - S_e^2/S_t^2$ where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983).

Statistical analysis

Means and standard deviations of all parameters were calculated. The D'Agostino–Pearson test was used to test for normality of distribution in the cephalometric variables prior to using parametric tests. Equality of variance was tested between each of the groups. The unpaired Student's and Welch's *t*-test were applied to each parameter to identify the differences between groups; the former was applied for the parameters that had equal variances and the later was applied for those that had unequal variances at the *F*-test.

Results

The coefficient of reliability for all cephalometric parameters indicated values within a range between 0.912 and 0.996, and satisfied the level of confidence (>0.90; Houston, 1983). Comparison between the cephalometric measurements of Japanese and Caucasian girls with Class II division 1 malocclusions is shown in Table 3 and Figure 2.

Cranial base relationships

The mean anterior (S–N) and total cranial base length (N–Ar) were significantly shorter in Japanese subjects compared with Caucasians ($P < 0.001$). However, the posterior cranial base length (S–Ar) and the saddle angle (N–S–Ar) did not show significant differences between the groups.

Maxillary skeletal relationships

The anteroposterior position of the maxilla was evaluated using S–A, Ar–A, and the S–N–A angle. The linear parameters, S–A and Ar–A, showed a significantly more protrusive maxilla in the Caucasian sample compared with the Japanese ($P < 0.001$), but the S–N–A angle did not indicate a significant difference between groups. According to the N–ANS distance, the Japanese had a significantly larger anterior upper facial height ($P < 0.05$). The PP/S–N angle was slightly larger in Japanese subjects, although the difference was not significant.

Mandibular skeletal relationships

The anteroposterior position of the mandible was evaluated by the S–B and S–N–B angle. According to these parameters, there was no significant difference in the anteroposterior position of mandible between Japanese and Caucasian. The anteroposterior position of the chin (S–Pog and the S–N–Pog angle) also showed no significant difference between the Japanese and the Caucasian sample. The vertical position of the mandible was evaluated using N–Me, and angles S–N/Go–Me and S–Ar–Go. All these parameters in the Japanese group indicated significantly more vertical development compared with Caucasians ($P < 0.01$, $P < 0.001$, and $P < 0.001$, respectively). The mean length of the mandibular ramus (Ar–Go) showed no significant difference between the groups, but the mandibular body (Go–Pog) and the total mandibular length (Ar–Pog) in the Caucasian sample were significantly longer compared with the Japanese sample ($P < 0.05$). Both groups had a similar gonial angle (Ar–Go–Me).

Inter-maxillary relationships

There was no significant difference between the groups in the anteroposterior relationship between the maxilla and mandible (ANB angle). The vertical height was evaluated by the ANS–Me distance and the PP/Go–Me angle. According to these measurements, the Japanese subjects had a significantly larger anterior lower facial height ($P < 0.05$, $P < 0.001$, respectively).

Table 3 Comparison of mean values between Japanese and Caucasian females with Class II division 1 malocclusions.

		Japanese Class II division 1		Caucasian Class II division 1		Significance
		Mean	SD	Mean	SD	
Cranial base relationships	S–N	61.4	2.4	65.4	2.7	***
	S–Ar	32.1	2.4	31.6	2.8	NS
	N–Ar	84.6	3.8	88.3	3.8	***
	N–S–Ar	126.8	4.4	127.6	5.3	NS
Maxillary skeletal relationships						
Anteroposterior	S–A	75.9	3.1	78.3	3.5	***
	Ar–A	78.2	3.5	81.9	4.5	***
	S–N–A	82.0	3.2	81.7	3.3	NS
Vertical	N–ANS	49.6	2.6	48.5	2.8	*
	PP/S–N	9.1	2.9	8.2	3.5	NS
Mandibular skeletal relationships						
Anteroposterior	S–B	95.6	4.4	94.9	4.8	NS
	S–N–B	75.9	3.1	75.4	3.1	NS
	S–Pog	107.1	5.0	106.7	5.6	NS
	S–N–Pog	75.2	3.0	76.0	3.4	NS
Vertical	N–Me	109.4	5.6	106.4	5.7	**
	S–N/Go–Me	41.1	5.2	37.0	5.6	***
	S–Ar–Go	143.5	5.1	139.2	7.4	***
Mandible	Ar–Go	38.1	3.7	39.2	3.9	NS
	Go–Pog	66.0	3.5	67.6	4.5	*
	Ar–Pog	93.0	4.6	95.1	5.5	*
	Ar–Go–Me	130.8	5.7	130.2	6.4	NS
Inter-maxillary relationships						
Anteroposterior	A–N–B	6.1	1.0	6.3	1.4	NS
Vertical	ANS–Me	62.6	4.6	60.9	4.5	*
	PP/Go–Me	32.0	5.1	28.9	4.7	***
Dentoalveolar relationships	U1/S–N	107.3	6.6	105.0	7.9	NS
	L1/Go–Me	96.6	4.8	94.3	6.6	*
	Occ.P/S–N	20.0	3.4	17.5	4.5	**

NS, no significant differences; $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

Dentoalveolar relationships

The inclination of the upper incisors was similar in both groups, but the lower incisors in the Japanese subjects were significantly more proclined compared with the Caucasian group. The occlusal plane inclination in the Japanese was significantly steeper compared with the Caucasians ($P < 0.01$).

Discussion

The short anterior cranial base length in the Japanese Class II division 1 sample does not represent a specific morphological feature of a Class II division 1 malocclusion, but rather a feature of the Japanese population in general. Masaki (1980) reported that Japanese Class I patients had a significantly shorter anterior cranial base length when compared with Caucasians. Cooke and Wei (1989) also found that southern Chinese boys had significantly shorter anterior cranial base length compared with Caucasian boys. Thus, a short anterior cranial base could be a racial feature of an Asian population who have a brachycephalic skeletal pattern. All previous studies have reported that Japanese patients have more excessive vertical skeletal development compared with Caucasians in both Class I

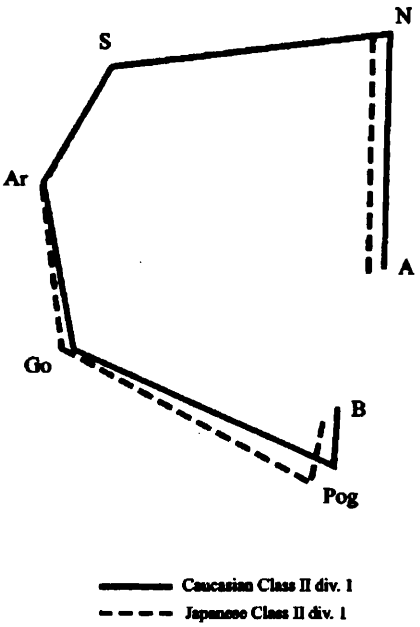

Figure 2 Comparison between Class II division 1 Japanese and Caucasian females.

(Masaki, 1980; Nezu *et al.*, 1982; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996) and Class II division 1 malocclusions (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989). Although a steeper mandibular plane has been reported in Japanese Class II studies (Miura *et al.*, 1958; Kuwahara, 1968; Iwasawa *et al.*, 1969, 1980; Ishii *et al.*, 2001), previous racial comparisons have concluded that there is no significant difference in the form and size of the mandible between Japanese and Caucasians for both Class I (Masaki, 1980; Miyajima *et al.*, 1996) and Class II division 1 malocclusions (Ishizuka *et al.*, 1989). Although a shorter mandibular body length and total mandibular length were shown in Japanese subjects in this study, these findings could not be the conclusive differences since low significance ($P < 0.05$) was calculated. The high-angle facial pattern of Japanese Class II division 1 subjects could be related to the more obtuse articular angle, leading to a greater backward rotation of the mandible, rather than an effect of the mandibular form. Therefore, the inter-maxillary disharmony seen in Japanese Class II division 1 subjects may be a feature of the vertical problem associated with a backward rotation of the mandible, whereas in Caucasians this disharmony may reflect a horizontal problem associated with an anterior positioned maxilla.

In the light of these findings, orthodontic treatment mechanics for Class II division 1 malocclusions should be considered depending on race. Nezu *et al.* (1982) stated that control of the chin, and vertical control of bite opening during orthodontic treatment was more important for Japanese patients, since that population had a tendency for facial axis opening; antero-posterior force may be more appropriate for Class II Caucasian malocclusions.

Conclusions

The morphological differences between Japanese and Caucasians with Class II division 1 malocclusions are as follows:

1. Caucasians had a significantly longer anterior cranial base length and a slightly longer mandibular body length.
2. Japanese had a significantly more obtuse articular angle, significantly steeper mandibular and occlusal plane angles, high-angle facial pattern, and significantly more proclined lower incisors.

Class II division 1 maxillary protrusion in Japanese girls may represent a vertical problem, whereas in Caucasians this may indicate a horizontal problem. The backward rotation of the mandible associated with Japanese and the anterior positioned maxilla in Caucasians could be the main reasons for the inter-maxillary disharmony.

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Craniofacial differences between Japanese and British Caucasian females with a skeletal Class III malocclusion

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SUMMARY The racial differences in craniofacial structures of 28 Japanese and 24 British Caucasian females with Class III malocclusions associated with a severe skeletal pattern were examined using lateral cephalograms. The mean age of the Japanese and Caucasian patients was 19.6 ± 3.5 and 20.2 ± 3.8 years (±SD), respectively. The mean values of 14 linear and 13 angular cephalometric parameters were compared between the two groups.

The results show that the Japanese females had a significantly reduced anterior cranial base ($P < 0.01$), more retrusive midfacial component ($P < 0.05$), and a significantly increased lower anterior facial height ($P < 0.01$) associated with a more obtuse gonial angle ($P < 0.05$) compared with the Caucasians. Analysis of the dento-alveolar component in Japanese patients indicated more proclined upper incisors ($P < 0.01$) compared with those of Caucasian subjects.

The reduced anterior cranial base and midfacial component, and the high-angle facial pattern in the Japanese population, may be morphological features based on race, and these skeletal features seem to be less favourable for a skeletal Class III growth pattern compared with the Caucasian population.

Introduction

The prevalence of Class III malocclusions varies among races. In the Caucasian population, Haynes (1970) and Foster and Day (1974) screened British girls aged 11–12 years, and noted that 1.6 and 3.2 per cent, respectively, of this population had a Class III malocclusion. On the other hand, Endo (1971) reported that a reversed occlusion was more prevalent (7.81 per cent) in 11-year-old Japanese girls. Similarly, Susami *et al.* (1971) also reported that the frequency of a reversed occlusion in Japanese females aged between 3 and 19 years was 4.24 per cent. The high frequency in the Japanese population was also confirmed in other Asian populations; the prevalence of Class III malocclusions in Chinese and Korean individuals ranges from 9.4 to 19.0 per cent (Chan, 1974; Baik *et al.*, 2000).

Previous investigators have described the morphological differences between Japanese and Caucasians with respect to Class I (Masaki, 1980; Nezu *et al.*, 1982; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996) and Class II (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Ishii *et al.*, 2002) malocclusions. Although the reported prevalence of Class III malocclusions is different among races, only a few studies have previously examined the morphological differences between Japanese and Caucasians with Class III malocclusions. Kishi (1991) and Uchiyama (1991), respectively, examined differences in the maxillary and mandibular skeletal features between Japanese and Caucasians with Class III malocclusions who required surgical corrections using the same sample. Kishi (1991) reported that Japanese Class III malocclusion is characterized by a reduced cranial base and more posteriorly positioned maxilla compared with Caucasians, and these features are common in the Japanese population including those with normal and other skeletal disharmonies. Uchiyama (1991) noted that Japanese patients with severe Class III malocclusions had an increased mandibular ramus and total mandibular length associated with a more superiorly positioned glenoid fossa compared with Caucasians. Furthermore, that author reported that Japanese Class III patients had a relatively larger mandible to maxilla and thus a more severe skeletal maxilla-mandibular disharmony than Caucasians. However, Uchiyama (1991) did not fully compare the mandibular form and vertical development of the craniofacial structure between the races. Ngan *et al.* (1997) clarified the cephalometric differences between Chinese and Caucasian patients with severe skeletal Class III malocclusions. They found a reduced anterior cranial base, a larger posterior cranial base, a smaller gonial angle, and a larger mandible in the Chinese. Similar findings were reported by Singh *et al.* (1998), who examined Class III Korean and Caucasian patients. They noted that Korean Class III patients had a reduced anterior cranial base and midfacial dimensions, and a larger mandible with a smaller gonial angle.

Although there is a lack of information about differences in the vertical development of craniofacial structure between Japanese and Caucasians with a Class III skeletal pattern, most previous comparative studies of Japanese and Caucasians with normal and Class II skeletal patterns concluded that the former population had more excessive vertical development and high-angle facial patterns (Masaki, 1980; Nezu *et al.*, 1982; Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996; Ishii *et al.*, 2002). However, other Asian Class III patients have a low-angle facial pattern associated with a smaller gonial angle compared with Caucasians (Ngan *et al.*, 1997; Singh *et al.*, 1998). These findings are conflicting, indicating that the craniofacial differences between Japanese and Caucasian patients with skeletal Class III malocclusions are still unclear, especially the racial differences in vertical development and the mandibular form.

The purpose of the present study was to characterize the morphological features of the craniofacial structure of Japanese females with skeletal Class III malocclusions and to compare these features with those of Caucasians with a skeletal Class III malocclusion, with the aim of clarifying the differences in craniofacial morphology between the two races.

Material and methods

Subjects

The pre-treatment lateral cephalometric radiographs of 28 Japanese and 24 British Caucasian females diagnosed with skeletal Class III malocclusions and scheduled for orthognathic surgery were examined. Both groups were randomly selected from the Department of Orthodontics, Matsumoto Dental University, Japan, and Eastman Dental Hospital, UK. All Japanese and Caucasian female patients satisfied the following criteria: (1) treatment planned for orthognathic surgery; (2) negative A–N–B angle; (3) Angle Class III molar relationship; and (4) no previous history of any orthodontic treatment when the cephalograms were taken. The mean age was 19.6 ± 3.5 years (±SD, range 15.1–27.1) and 20.2 ± 3.8 years (±SD, range 15.3–27.4), for the Japanese and Caucasians, respectively.

Cephalometric analysis

All lateral cephalometric radiographs were taken using the same cephalostat system for each group. The image magnification of the cephalostat for the Japanese and Caucasian patients was 10 and 7 per cent, respectively, and all linear measurements reported in this study were adjusted accordingly. All lateral cephalograms of each subject were traced by the same investigator. The selected landmarks were digitized and converted to an x–y coordinate system (WinCeph, Rise Corporation, Sendai, Japan) (Figure 1). The 14 linear and 13 angular measurements represented the original parameters and those derived from the analyses of Steiner (1953) and Jarabak and Fizzell (1972).

Error of measurements

All 52 lateral cephalograms were re-traced and re-digitized a few weeks after the initial analysis. The error of the method was examined by the coefficient of reliability, calculated for each

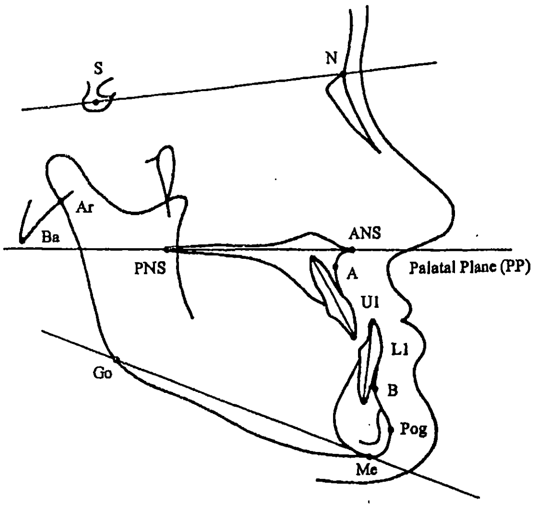

Figure 1 Cephalometric landmarks recorded in the present study. A, the deepest midline point on the premaxilla between the anterior nasal spine and prosthion. ANS, the most anterior point of the nasal floor; tip of the premaxilla on midsagittal plane. Ar, the point of intersection of the dorsal contour of the process articularis mandibulae and os temporale. B, the deepest midline point on the mandible between infradentale and pogonion. Ba, the most inferior point on the anterior margin of the foramen magnum in the midsagittal plane. Go, the most posterior inferior point at the angle of the mandible. L1, the axis of the lower central incisor. Me, the most inferior point on the symphysis of the mandible in the median plane. N, craniometric point where the midsagittal plane intersects the most anterior point of the nasofrontal suture. PNS, the most posterior point at the sagittal plane on the bony hard palate. Pog, the most anterior point on the symphysis of the mandible. S, the centre of the pituitary fossa. U1, the axis of the upper central incisor.

measurement as follows: coefficient of reliability $= 1 - S_e^2/S_t^2$, where S_e^2 is the variance due to random error, and S_t^2 is the total variance of the measurements (Houston, 1983). The results are presented in Table 1.

Statistical analysis

The mean and standard deviation of each parameter were calculated. D'Agostino–Pearson's test was used to determine the distribution of cephalometric variables prior to using parametric tests. Equality of variance was tested between each group by the F-test. The unpaired Student's and Welch's *t*-tests were applied to each parameter to test the significance of differences between groups; the former was applied to parameters that had equal variances, while the latter was applied to those that had unequal variances at the F-test.

Results

The coefficient of reliability for all cephalometric parameters satisfied the level of confidence above 0.90 (Houston, 1983). The results of comparison between cephalometric measurements of Japanese and Caucasian females with skeletal Class III malocclusion are presented in Table 1 and Figure 2.

Cranial base relationships

The mean anterior cranial base (S–N) was significantly reduced in Japanese patients compared with Caucasians ($P < 0.01$). However, the other cranial base parameters, posterior cranial base length (S–Ar), total cranial base length (N–Ar), saddle angle (the N–S–Ar angle) and the cranial base angle (the N–S–Ba angle), were not significantly different between the two groups.

Maxillary skeletal relationships

The anteroposterior position of the maxilla was evaluated by measuring S–A, Ar–A, and the S–N–A angle. Only Ar–A was significantly reduced in the Japanese females compared with the Caucasians ($P < 0.05$). S–A and S–N–A angle were not significantly different between the groups. Based on the parameters of vertical development, N–ANS and PP/S–N angle were not significantly different between the groups.

Mandibular skeletal relationships

The anteroposterior position of the mandible was evaluated by measuring S–B and the S–N–B angle. Although the linear parameter was significantly increased in the Japanese females compared with the Caucasian group ($P < 0.05$), there was no significant difference in the angular parameter between the two groups. The

Table 1 Comparison of various cephalometric parameters between Japanese and Caucasian females with skeletal Class III malocclusions.

			Japanese $n = 28$			Caucasian $n = 24$			Significance
			Coefficient of reliability	Mean	SD	Coefficient of reliability	Mean	SD	
Cranial base relationships									
	S–N	(mm)	0.992	62.5	3.1	0.994	65.0	3.2	**
	S–Ar	(mm)	0.950	31.4	3.4	0.977	30.3	2.6	NS
	N–Ar	(mm)	0.956	84.1	4.1	0.981	85.8	4.0	NS
	N–S–Ar	(°)	0.974	123.8	5.5	0.969	124.4	5.6	NS
	N–S–Ba	(°)	0.973	131.6	4.8	0.966	131.2	5.5	NS
Maxillary skeletal relationships									
Anteroposterior	S–A	(mm)	0.990	76.8	4.0	0.986	78.7	3.5	NS
	Ar–A	(mm)	0.983	76.3	3.6	0.993	78.7	3.7	*
	S–N–A	(°)	0.987	80.1	4.2	0.986	80.2	4.3	NS
Vertical	N–ANS	(mm)	0.967	51.4	2.6	0.983	50.8	3.9	NS
	PP/S–N	(°)	0.949	10.0	3.5	0.944	9.4	3.3	NS
Mandibular skeletal relationships									
Anteroposterior	S–B	(mm)	0.989	112.2	5.3	0.984	108.9	4.8	*
	S–N–B	(°)	0.991	84.3	4.7	0.991	84.1	5.0	NS
	S–Pog	(mm)	0.996	125.8	6.4	0.993	122.8	5.0	NS
	S–N–Pog	(°)	0.990	84.3	4.8	0.993	84.7	5.3	NS
Vertical	N–Me	(mm)	0.999	120.3	7.5	0.996	114.6	8.0	*
	S–Go	(mm)	0.945	72.3	4.8	0.991	70.6	4.8	NS
	S–N/Go–Me	(°)	0.996	40.9	6.1	0.996	36.8	7.5	*
	S–Ar–Go	(°)	0.944	139.2	7.3	0.966	138.5	7.0	NS
Mandible	Ar–Go	(mm)	0.939	45.7	4.1	0.986	45.2	5.0	NS
	Go–Pog	(mm)	0.968	76.8	4.8	0.980	77.5	4.8	NS
	Ar–Pog	(mm)	0.996	112.4	5.6	0.992	111.2	4.6	NS
	Ar–Go–Me	(°)	0.968	137.9	7.1	0.972	133.9	6.3	*
Inter-maxillary relationships									
Anteroposterior	A–N–B	(°)	0.993	–4.2	2.4	0.996	–4.0	2.3	NS
Vertical	ANS–Me	(mm)	0.996	69.2	6.5	0.989	64.1	5.3	**
	PP/Go–Me	(°)	0.989	30.8	6.4	0.989	27.4	7.0	NS
Dento-alveolar relationships									
	U1/S–N	(°)	0.997	110.3	6.6	0.995	105.6	5.9	**
	L1/Go–Me	(°)	0.999	75.0	7.4	0.996	78.5	5.0	NS

NS = not significant, $*P < 0.05$, $**P < 0.01$.

anteroposterior position of the chin evaluated by S–Pog and the S–N–Pog angle did not show a significant difference between the Japanese and Caucasian groups. The vertical position of the mandible was evaluated by measuring N–Me, S–Go, S–N/Go–Me angle, and S–Ar–Go angle. The total anterior facial height (N–Me) and the mandibular plane angle (the S–N/Go–Me angle) in the Japanese group were significantly increased compared with the Caucasians ($P < 0.05$), but the posterior facial height (S–Go) and the saddle angle (the S–Ar–Go angle) were not significantly different. The form of the mandible was examined by Ar–Go, Go–Pog, Ar–Pog, and the Ar–Go–Me angle. All linear measurements of the mandible indicated no significant difference between the two groups, but the Japanese females had a significantly more obtuse gonial angle (the Ar–Go–Me angle) compared with the Caucasian patients ($P < 0.05$).

Inter-maxillary relationships

The anteroposterior relationship between the maxilla and mandible was evaluated by the A–N–B angle. There was no significant difference

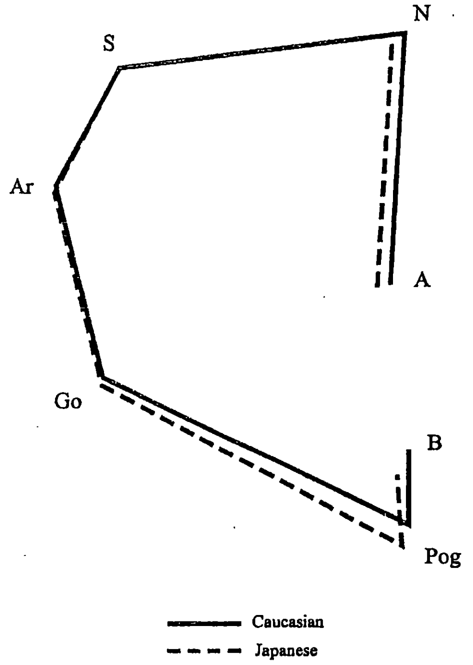

Figure 2 Comparison between representative landmarks of Japanese and Caucasian with severe Class III malocclusions.

between the groups. The vertical distance between the palatal and mandibular planes was examined by ANS–Me and the PP/Go–Me angle. The linear parameter showed a significantly increased lower anterior facial height in the Japanese patients ($P < 0.01$), but the angular parameter did not show a significant difference between the two groups.

Dento-alveolar relationships

The Japanese females had significantly more proclined upper incisors compared with the Caucasians ($P < 0.01$), but the inclination of the lower incisors was similar between the groups.

Discussion

The major finding of the present study was the reduced anterior cranial base in Japanese females with skeletal Class III malocclusions compared with their Caucasian counterparts. In general, the majority of previous investigations that compared the craniofacial morphology between Asians and Caucasians reported that Asians had a reduced anterior cranial base not only in those with a Class I occlusion (Masaki, 1980; Nezu *et al.*, 1982; Cooke and Wei, 1989; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996), but also in subjects with Class II (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Ishii *et al.*, 2002) and Class III (Kishi, 1991; Ngan *et al.*, 1997; Singh *et al.*, 1998) malocclusions. Fukui *et al.* (1992) examined the morphological features of the maxilla and cranial base in Taiwanese with a pseudo anterior crossbite, and compared their findings with those of Japanese and American whites. The maxilla and dento-alveolar components of the Taiwanese were slightly different from those of the Japanese, but the form of the cranial base was similar in both races. They stated that the development of the maxilla and the dento-alveolar component might be influenced by their oral functions, but the form of the cranial base could directly reflect the genetic characteristics. The present study characterized the typical racial differences in craniofacial morphology among Asian and Caucasian populations.

With respect to the mandibular dimensions, there was no significant difference between the Japanese and Caucasian groups; the mandible was similar in size in both groups. However, the cranial base and midfacial component of the Japanese patients were much more reduced compared with the Caucasian group; a reduced midfacial dimension was found in previous studies of Class III patients (Kishi, 1991; Ngan *et al.*, 1997; Singh *et al.*, 1998). These results indicate that Asian skeletal Class III patients have a relatively larger mandible to the cranial base and maxilla. Uchiyama (1991) reported similar findings, and concluded that these more severe skeletal abnormalities were less favourable with regard to orthodontic and orthognathic treatments of Japanese and other Asian populations.

A steeper mandibular plane angle (the S–N/Go–Me angle) associated with a more obtuse gonial angle (the Ar–Go–Me angle) was also found in the Japanese females with skeletal Class III malocclusions compared with Caucasians in the present study. These results are in conflict with the findings of Ngan *et al.* (1997) and Singh *et al.* (1998), respectively, who compared skeletal

Class III Chinese and Korean with Caucasians; both investigators reported that Chinese/Korean had a smaller mandibular plane angle and gonial angle. From this point of view, the morphological features of the craniofacial structure of Japanese Class III patients seems to be different from the Chinese and Korean patients, although all three races are categorized into Mongoloid. The results of Chui and Kawamoto (1990) could support this assumption. They compared Chinese children with a Class III malocclusion with Japanese subjects. They stated that both races had similar skeletal features, but Chinese subjects had a significantly smaller mandibular plane angle compared with the Japanese. Thus, Japanese Class III patients have more excessive vertical development associated with a larger mandibular plane angle and gonial angle compared with Caucasian Class III patients, and this racial feature is supported by the comparative studies between Japanese and Caucasian Class I (Masaki, 1980; Nezu *et al.*, 1982; Deguchi *et al.*, 1993; Miyajima *et al.*, 1996) and Class II (Ono *et al.*, 1986; Yamaki, 1987; Ishizuka *et al.*, 1989; Ishii *et al.*, 2002) subjects.

The Japanese females in the present study had a reduced anterior cranial base, more retrusive midfacial component, and a high-angle facial pattern with a steeper mandibular plane compared with the Caucasians. In general, these differences between Japanese and Caucasians with surgical Class III were not specific to the skeletal Class III growth pattern; they might be common racial differences. However, these common racial features in the Japanese would not be favourable for the Class III skeletal pattern, as the retrusive midfacial component indicated a more posteriorly positioned maxilla, whilst a steeper mandibular plane made the effective mandibular length more increased. In other words, Japanese individuals tend to have a retrognathic maxilla and prognathic mandible compared with Caucasians. These common skeletal features based on racial differences might be less favourable for correction of a Class III skeletal pattern, and consequently, severe skeletal Class III abnormalities are more likely to occur among the Japanese population compared with Caucasians.

Conclusions

The results of this study showed that the major craniofacial differences between Japanese and Caucasian females with skeletal Class III malocclusion were as follows. Japanese females had: (1) a significantly reduced anterior cranial base; (2) a significantly more obtuse gonial angle; (3) a high-angle facial pattern with a significantly increased lower anterior facial height; and (4) significantly more proclined upper incisors. These differences in subjects with a skeletal Class III malocclusion might represent common differences in skeletal features between the two racial groups, but reduced midfacial component and high-angle facial pattern in Japanese population would be less favourable for correction of a Class III skeletal pattern compared with Caucasians.

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