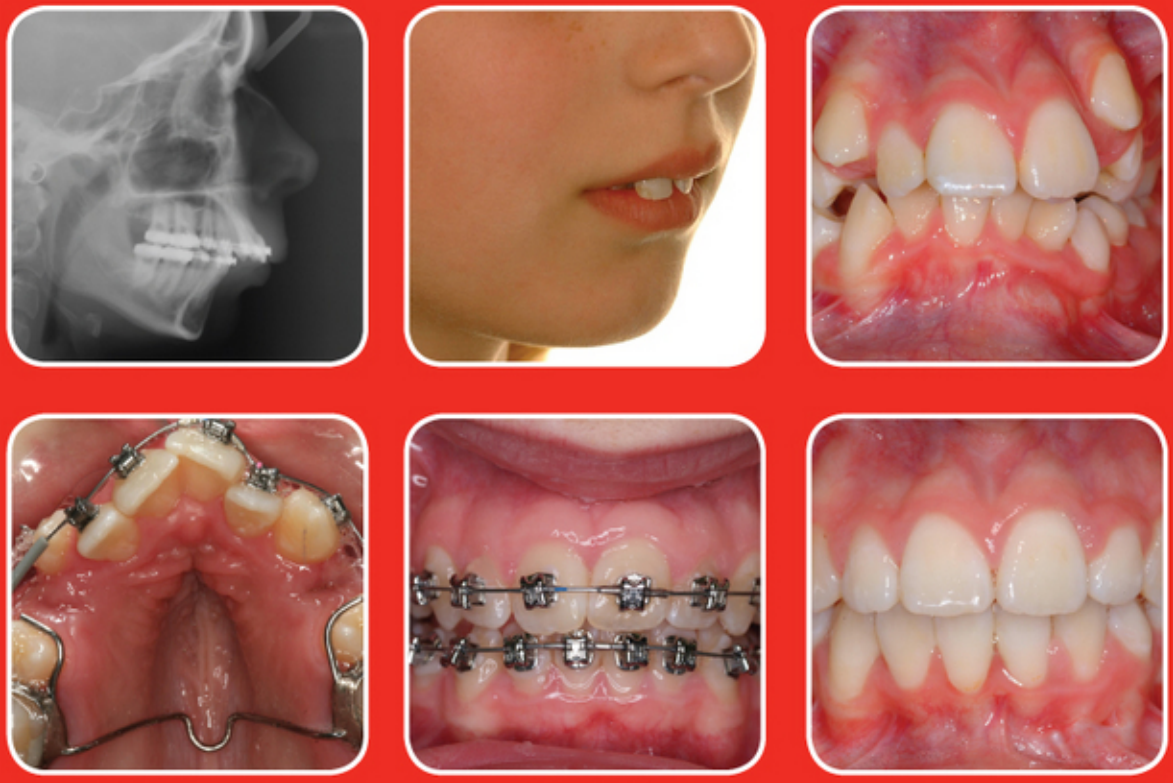
CLINICAL CASES SERIES

Clinical Cases in Orthodontics

Martyn T. Cobourne, Padhraig S. Fleming, Andrew T. DiBiase and Sofia Ahmad



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Preface

We think that orthodontics is one of the most interesting and challenging of the dental specialties. Although we might be biased in this assumption, there are some persuasive reasons for believing that it is true. The treatment of malocclusion represents a combination of science and artistic flair, and is often, although not exclusively, carried out on a young and vibrant population. The results of orthodontic treatment and the positive impact that it can have on the patient can also be intensely rewarding for the clinician. Moreover, developments in diagnostic tools, appliance systems and orthodontic materials continue at some considerable pace within the profession, which provides considerable stimulus to the contemporary clinician.

We have written this textbook primarily to be used as a tool for dental professionals who wish to broaden their experience and understanding of clinical orthodontics. The intention has been to show a wide variety of individual cases and clinical scenarios that illustrate many of the problems commonly seen during development of the craniofacial region, with emphasis on the jaws, dentition and occlusion. All of these cases have been treated or directly supervised by the authors, primarily in secondary care, following referral from general practitioners and specialists. We have attempted to illustrate a wide variety of problems that present in the orthodontic clinic, both common and rare, and demonstrate different approaches to their management. Relevant discussion around the etiology, diagnosis and planning of these cases is included in each presentation. We hope that this book will be of particular benefit to postgraduate orthodontic students preparing for their MSc, MClinDent, DDS and Membership examinations in orthodontics. Indeed, a number of the cases included have been successfully used in recent sittings of these examinations. However, the clinical focus underlying this text should mean that it will also be of benefit to other dental professionals involved in management of the developing occlusion, including therapists and undergraduate dental students – who indeed, represent the orthodontists of the future.

It was not our intention to write a definitive textbook on orthodontics, but rather to illustrate contemporary practice using clinical cases and individual examples. Therefore, the introduction to each chapter gives a general overview of the subject area, which is then followed by a series of cases with appropriate questions and answers. We have included the answers to these questions within the cases to avoid the need for constant reference to other parts of the book. Hopefully, this will make it relatively straightforward for the reader to follow the treatment strategies that have been used. In some of the clinical scenarios, more emphasis has been given to clinical examination and diagnosis; whilst in others, questions focus on the treatment that has been carried out. Indeed, many of these cases have been chosen to illustrate specific aspects of etiology, diagnosis, treatment planning or use of mechanics in the management of malocclusion. This problem-based approach of discussing aspects of malocclusion should allow practising clinicians to develop their skills in the management and care of orthodontic patients, from initial assessment, through to the completion of treatment. However, whilst we strive to achieve clinical excellence for the cases that we treat, we did want to illustrate those that had been treated 'in the real world' and therefore have not excluded examples where difficulties have been experienced. In addition, some cases have the cephalometric values provided in

the diagnostic information, whilst some do not. We believe that cephalometrics should be used to supplement the clinical diagnosis and felt that the reader would benefit from having them provided in some, but not all, of the case records included.

In setting out this book, we have attempted to arrange the chapters into a series that progresses logically, although there can be considerable flexibility in the precise order in which they can be read, particularly those chapters dealing with specific malocclusions. Chapter 1 provides an introduction to clinical examination and diagnosis of the orthodontic patient, including the use of radiographic and cephalometric analysis in treatment planning. This chapter also covers aspects of the patient medical history that can be of relevance to orthodontic treatment. Chapter 2 is concerned with postnatal development of the dentition and has been designed to include individual examples of anomalies that can occur during establishment of the dentition (both common and rare), the use of interceptive treatment and major aspects of tooth agenesis. Chapters 3–6 are organized according to the conventional classification of malocclusion and include the management of class I, class II division 1, class II division 2 and class III cases. Chapter 7 covers problems associated with tooth impaction in the permanent dentition and Chapter 8 focuses on fixed orthodontic appliances, using individual examples to demonstrate issues relating to their use and the application of treatment mechanics. Chapter 9 covers the subject of post-treatment stability and the management of retention, whilst Chapter 10 explores diagnosis and treatment of cases requiring a combined orthodontic and surgical approach to correct significant skeletal discrepancies. Finally, Chapter 11 is concerned with the etiology and management of developmental conditions that can affect the craniofacial region.

Inevitably, amongst all of the cases that have been used, there is some repetition of problems that can occur in relation to malocclusion; however, we hope that this adds rather than subtracts from the quality of the text. Indeed, many different philosophies and approaches exist regarding the management of malocclusion and we hope that many of these have been suitably illustrated. This book does not represent a comprehensive text, but hopefully does cover most aspects of contemporary clinical orthodontics through the documentation of treated cases. We hope that the style and content of the book is stimulating and that you as the reader are broadly in agreement with the treatment decisions that have been made and satisfied with the final results that have been achieved.

Martyn T. Cobourne
Padhraig S. Fleming
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1

Clinical and Cephalometric Analysis

Introduction

Orthodontics is the area of dentistry concerned with the management of deviations from normal occlusion or malocclusion and involves treatment of children, adolescents and, increasingly, adults. Malocclusion is a variation on normal occlusion and is not a disease entity. Consequently, orthodontic planning and management does not involve binary decisions, but rather evaluation of a range of possibilities to decipher the most appropriate option for each individual.

An ideal static occlusion is characterized by class I molar and incisor relationships, with well-aligned teeth. An acceptable occlusion, however, develops naturally in only 30–40% of the population in Western societies. The occurrence of an acceptable occlusion is multi-factorial, although important factors include the size of the jaws; the relationship of the jaws to each other; the size, number and morphology of the teeth; and the morphology and behaviour of the lips, tongue and peri-oral musculature.

Given that malocclusion does not represent a pathological process but rather a variation from an accepted norm, there is little agreement, even among orthodontists, as to when orthodontic treatment becomes necessary (Richmond *et al.*, 1984). As a consequence, a variety of orthodontic indices have been developed to ration treatment where care is provided as part of a public health service, such as in the UK and Scandinavia (Brook and Shaw, 1989), based primarily on aesthetic and dental health impairment.

The demand for orthodontic treatment has increased universally, particularly over the past two decades. A desire to enhance dental appearance is the underlying motivation for most patients who seek orthodontic treatment (Shaw *et al.*, 1991). Furthermore, the lay public has developed an increasing awareness of the importance of the dentition to overall attractiveness. Carefully planned and well-executed orthodontics can also enhance facial appearance, which in turn has been linked to improved social skills, greater desirability, higher intellectual ability and enhanced occupational prospects (Shaw *et al.*, 1979).

Deviation from occlusal norms may leave children susceptible to harassment, teasing and bullying, with obvious psychosocial implications (Shaw *et al.*, 1980; Seehra *et al.*, 2011). Consequently, orthodontic treatment may have significant psychosocial benefits (Shaw *et al.*, 1980; O'Brien *et al.*, 2003) and can often lead to improved oral health-related quality of life. Similarly, combined orthodontic–surgical treatment has been linked to notable enhancement of both self-esteem and quality of life (Arndt *et al.*, 1986).

The undoubted benefits of orthondontics are, however, reliant on careful diagnosis, planning and management. Clinical assessment and radiographic analysis are central to the formulation of appropriate treatment decisions leading to the best aesthetic and functional outcome from treatment.

As in any other area of medicine or dentistry, to reach a diagnosis in orthodontics requires a thorough history, examination and special tests. A comprehensive history should be undertaken to clarify the motivation for treatment, the dental and orthodontic history, and any relevant medical history

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that might impact on the provision of orthodontic treatment (Patel *et al.*, 2009).

Dental History

A history of dental attendance is relevant in relation to caries experience and the presence of restorations. Caries experience is the best predictor of future caries. Poor oral hygiene predisposes to two risks of treatment: gingivitis and demineralization. Premature loss of primary teeth due to caries may also have consequence for the developing dentition. In particular, early loss of primary teeth may hasten or retard eruption of permanent teeth and lead to space loss, which can result in centre line discrepancies or potential tooth impaction.

What has led to crowding of the second premolars in Figure 1.1?

Early loss of the second primary molars has allowed the first permanent molars to drift forward in the dental arch. The second premolars are most vulnerable to space loss in this region.

Restorations

Heavily-restored teeth may pose problems in relation to bonding, necessitating alteration of the bonding protocol, with sandblasting of amalgam and precious metal restorations proven to enhance bond strength (Zachrisson *et al.*, 1995; Büyükyilmaz *et al.*, 1995).

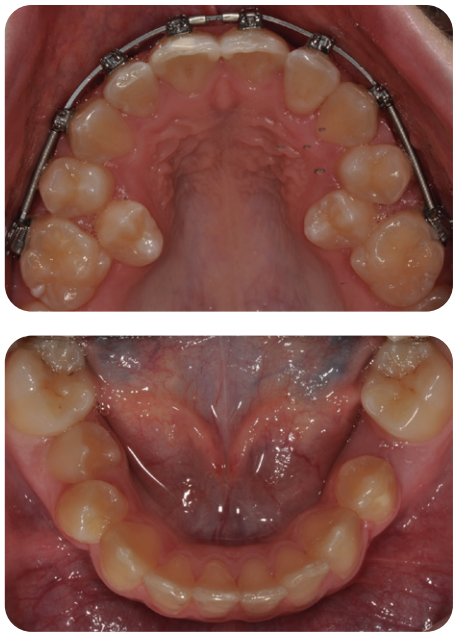

Figure 1.1

There is conflicting evidence in relation to the susceptibility of root canal-treated teeth to root resorption during treatment. Nevertheless, the health of root-treated teeth should be monitored throughout treatment.

Trauma

A history of trauma to the dentition should be investigated. Previously traumatized teeth risk loss of vitality irrespective of orthodontic treatment. This potential eventuality should be discussed at the outset as part of the informed consent process. In addition, traumatized teeth may also be at risk of undergoing more apical root resorption during treatment. The nature and timing of the traumatic injury has a bearing on further treatment (Kindelan *et al.*, 2008) (Table 1.1).

Previous orthodontics

Increasingly, potential orthodontic patients, particularly adults, may have undergone previous treatment. Details of the original malocclusion may help to decipher the aetiology of both the presenting and residual malocclusion. Potential consequences of incomplete treatment include residual malalignment and spacing, traumatic overbite, residual overjet, crossbite and relapse. Previous failure to complete a course of orthodontic treatment may raise questions with respect to compliance (Murray, 1989). Where compliance is questionable, it may be inadvisable to embark on an ambitious course of orthodontic treatment.

Furthermore, contemporaneous records are important to reveal deleterious effects of the primary phase. Rarely, significant root resorption may limit the feasibility for retreatment.

Table 1.1 Timing of further treatment for traumatic injury

Type of injury	Recommended observation period before orthodontic treatment
Fracture without pulpal involvement	3 months
Subluxation	3 months
Extrusive luxation	3 months
Minor lateral luxation	3 months
Moderate/severe lateral luxation	1 year
Intrusion	1 year
Avulsion	1 year

CASE 1.1
This 17-year-old female presented with a class III malocclusion on a moderate skeletal class III pattern with an average lower facial height. She has had previous orthodontic treatment to align her maxillary teeth, involving extraction of maxillary first premolars. She remains concerned in relation to her facial appearance and occlusion.

What do you notice with respect to the radiographic appearance of the maxillary incisors (Figure 1.2)?

The maxillary incisors, particularly the UR1, UL1 and UR2, have experienced extensive root resorption during the first phase of treatment.

How will this finding influence further management?

The patient is keen to undergo combined orthodontic–surgical treatment to address her malocclusion comprehensively. Prior to instituting such treatment, the patient will be counselled in relation to the likelihood of further resorption. If the patient opts to undergo combined treatment, attempts will be made to avoid an upper fixed appliance. If an appliance is to be placed, light forces will be applied, there will be a premium on excellent oral hygiene and the duration of treatment will be necessarily short with realistic objectives.

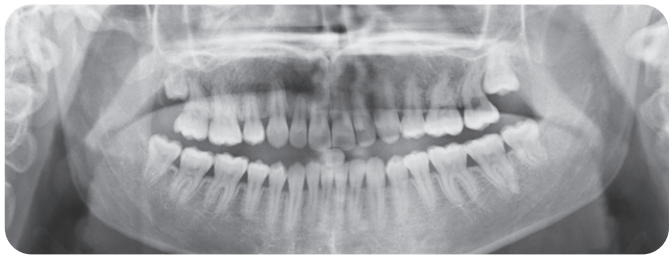

Figure 1.2

Family History

The contribution of genetic factors to malocclusion has been established in family and twin studies. Concordance of occlusal patterns in monozygotic twins provides support for the influence of genetics on malocclusion, while discordance between monozygotic twins suggests occlusal relationships may be under greater environmental influences. A family history of severe class III malocclusion; abnormalities of tooth number and form; and ectopic dental development should be considered when planning treatment for relatives.

Cranio-facial morphology in class II and class III groups tends to have strong heritability, although the association is less clear in class I subjects. In particular, familial cephalometric studies have shown that mandibular length may be reduced, with a smaller mandibular body and retruded mandible in class II patients (Harris, 1975).

Furthermore, mandibular prognathism in monozygotic twins is six times higher than among dizygotic twins (Litton *et al.*, 1970). A Japanese study showed that 70% of patients undergoing orthognathic surgery for class III malocclusion have a first-degree relative with mandibular prognathism (Watanabe *et al.*, 2005). Therefore, a history of orthognathic intervention in a family member should be considered when planning early treatment and anticipating future growth in class III malocclusion.

There is also a familial link in relation to supernumerary teeth. Inheritance does not follow a simple Mendelian pattern, being variously described as an autosomal dominant trait with incomplete penetrance, a sex-linked trait and an autosomal recessive trait with lesser penetrance in females (Fleming *et al.*, 2010). Hypodontia has also been linked to specific mutations related to *MSX1* and *PAX9* genes, and tends to co-exist with microdontia (Brook, 1984). Genetic factors are also implicated in palatal impaction of maxillary canines; dental transpositions; infra-occlusion of primary molars; and impaction of first permanent molars.

Genetic susceptibility to severe root resorption during orthodontic treatment has also been attributed

to mutations of genes encoding interleukin-1 beta (IL-1β). Consequently, the potential for extensive resorption should be anticipated in family members. Treatment objectives may be modified accordingly.

Medical History

A comprehensive medical history should be taken for each patient. Whilst there are few medical conditions that contraindicate orthodontic treatment in a compliant dentally fit individual, several can impact on the delivery of care.

Heart defects with risk of infective endocarditis

Infective endocarditis is a rare cardiac condition with mortality rates of up to 40%. Previously, antibiotic prophylaxis was recommended for patients with structural heart defects predisposing to formation of valvular vegetations, which may culminate in infective endocarditis. High-risk conditions include previous infective endocarditis, prosthetic heart valves and acquired valvular disease with stenosis or regurgitation. However, under new National Institute of Health and Clinical Excellence (NICE) guidelines in the UK, the use of prophylactic antibiotics is no longer recommended for dental procedures (NICE, 2008).

Is antibiotic cover required prior to any orthodontic procedure?

Historically, antibiotic cover has been recommended for dental procedures involving gingival manipulation on patients with structural defects of the heart. The rationale for use of antibiotics was to counteract transient bacteraemia that may lead to infective endocarditis. Susceptible orthodontic procedures included placement of separators and bands, and removal of appliances. However, NICE now advises that use of prophylactic antibiotics is not indicated (NICE, 2008). The cost-efficacy of prophylaxis is unproven. The use of antibiotics has a reported attendant morbidity with fatal anaphylaxis of up to 12–25 cases per million (Ahlstedt, 1984). This risk is thought to outweigh the benefits of their use. Therefore, in current practice, antibiotic cover is not routinely recommended for patients with a structural heart defect undergoing orthodontic treatment.

Bleeding disorders

Conditions such as haemophilia do not preclude orthodontic treatment; however, treatment should involve haematological input. These patients are also at higher risk of carrying blood-borne viral infections, including HIV or hepatitis.

CASE 1.2

This 15-year-old male presented with haemophilia A. He has mild crowding of both arches and is anxious to have orthodontic treatment (Figure 1.3).

Figure 1.3

How will his history of haemophilia A affect his management?

Oral hygiene

Prior to instituting treatment, the importance of excellent oral hygiene should be emphasized. This may necessitate sessions with a dental hygienist or oral hygiene educators. A plaque score below 10% should be achieved before committing to treatment.

Treatment planning

If possible treatment should be undertaken on a non-extraction basis, obviating the risks of extractions and complex haematological management of extractions. Space creation may therefore be achieved by arch lengthening involving transverse or anteroposterior arch expansion or by inter-proximal reduction.

Management of extractions

Where extractions are necessary, these should be managed with input from physicians. Factor VIII production may be increased with 1-desamino-8-D-arginine vasopressin (DDAVP). Cryoprecipitate, Factor VIII in isolation or fresh frozen plasma may be used to replace missing Factor VIII. An anti-fibrinolytic, tranexamic acid, is also useful to stabilize clot formation.

Gingival trauma and soft tissue irritation

Efforts should be made to make the appliance as safe and unobtrusive as possible. In particular, wire ligatures should be avoided and use of self-ligating brackets can be considered. Soft tissue trauma from sharp and long wire ends should be avoided.

Allergies

The most important allergies in relation to orthodontic treatment are those associated with exposure to latex and nickel. Hypersensitivity reactions occurring with either allergen may be immediate (Type I) or delayed (Type IV); however, those related to nickel are typically Type IV reactions. Type I sensitivity is antibody mediated and may present as a localized urticaria or as anaphylaxis. Type IV hypersensitivity typically results in localized allergic contact dermatitis.

Latex allergy: Allergy to natural rubber latex is becoming increasingly prevalent with powdered gloves harbouring latex allergens. Individuals susceptible to allergic reactions include atopic individuals with allergic rhinitis, asthma and eczema; and patients with spina bifida.

How should potential orthodontic patients with suspected latex allergy be managed?

- **Definitive diagnosis:** Latex allergy can be diagnosed with either patch testing or pin prick testing, although the latter is more reliable.
- **Staff training and communication:** Staff should be aware of emergency protocols for dealing with anaphylactic reactions and auxiliary staff should be aware of the diagnosis.
- **Appointment and surgery management:** Appointments should be scheduled for the early morning with use of a latex-screened area to segregate latex-free products to avoid contamination.
- **Appliance design and handling:** The use of latex products should be avoided. Latex-containing gloves should be replaced with alternatives, including nitrile or vinyl. The use of elastomeric ties could be avoided with use of self-ligating brackets. Space closure should be undertaken with nickel–titanium coils. Where inter-maxillary elastics are required, latex-free elastics can be used, although they are subject to greater force degradation.

Nickel allergy: Nickel allergy is relatively common, affecting over 10% of females (Nielsen and Menne, 1993). Typically, Type IV hypersensitivity reactions present on the skin as contact dermatitis; however, intra-oral manifestations are less common. There appears to be a higher threshold nickel concentration required intra-orally to induce a reaction. Nickel–titanium archwires and auxiliaries, and stainless steel products, including archwires, brackets and headgear, all contain nickel. Hence, vigilance should be exercised when using these materials in at-risk patients.

What is the recommended protocol in a 25-year-old female patient with a suspected nickel allergy?

- **Definitive diagnosis:** Patch testing may be performed by a dermatologist to confirm the diagnosis.
- **Treatment:** Consideration could be given to use of nickel-free brackets, e.g. ceramic, gold, titanium or polycarbonate brackets. The use of nickel–titanium archwires should be avoided where intra-oral signs of a reaction are noted. These wires may be replaced by fibre-reinforced composite wires,

stainless steel wires with reduced nickel content, titanium molybdenum alloy or titanium niobium wires. Rarely, in severe cases, consideration could be given to the use of clear plastic aligners.

Diabetes

Poorly controlled diabetics are more susceptible to periodontal breakdown. Excellent oral hygiene therefore needs to be maintained during orthodontic treatment.

Immunosuppression

Certain immunosuppressive drugs such as cyclosporin can cause gingival hyperplasia or drug-induced gingival overgrowth in the presence of good oral hygiene (Figure 1.4). Again, excellent oral hygiene is imperative for these patients throughout treatment, as gingival swelling may become more marked with poor plaque control (Figure 1.5).

Epilepsy

Epilepsy is a common neurological condition, occurring in 2–5% of individuals. It is considered active if a patient is taking medication or has had a seizure within the last 2 years. If treatment is to be considered, the condition should be well-controlled. Removable appliances are best avoided in epileptics as displacement of the appliance during a seizure risks airway compromise. Consequently, fixed functional appliances or class II correctors are preferred to removable alternatives. Anti-convulsants, including phenytoin, may result in gingival hyperplasia, with 50% of individuals affected within 3 months of commencing the medication. Second-line medications, including carbamazepine, may result in glossitis, xerostomia or oral ulceration.

Figure 1.4

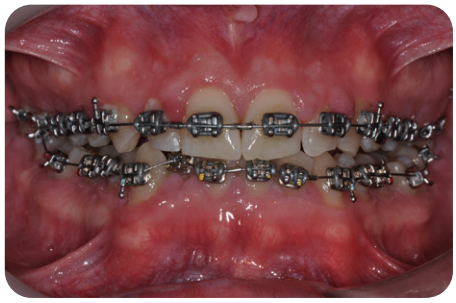

Figure 1.5

Childhood malignancy

Childhood malignancy and its treatment may have significant implications for orthodontic treatment. The most common malignancy is leukaemia, with acute lymphoblastic leukaemia accounting for 25% of childhood tumours. Treatment of acute leukaemia may involve bone marrow transplantation or chemotherapy. Immunosuppressants and total body irradiation are used following bone marrow replacement to prevent graft-versus-host disease.

Treatment of malignant disease in childhood with either radiotherapy or chemotherapy can result in either tooth agenesis or root shortening. Other tumours of the head and neck requiring early radiotherapy may include retinoblastoma and sarcomas.

What side effects of head and neck radiotherapy are of relevance to orthodontics?

- Root shortening and arrested tooth development
- Reduced growth hormone production and impaired bone growth: This may result in reduced craniofacial dimension
- Reduced bone density
- Mucositis
- Arrested root development
- Premature apical closure
- Microdontia
- Hypodontia
- Delayed dental development
- Enamel defects

(Sheller and Williams, 1996)

What are the orthodontic implications of childhood malignancy and its treatment?

- Premium on excellent oral hygiene
- Use of light forces
- Early termination of treatment

- Consideration of compromised treatment
- Relevant medications

Bisphosphonates

Bisphosphonates inhibit the resorption of trabecular bone by impairing osteoclastic activity to maintain bone density. They have found particular application in the management of osteoporosis, and may be prescribed to reduce hypercalcaemia following bone metastasis. Potential side effects of bisphosphonates relevant to orthodontics include osteonecrosis of the jaws, delayed eruption and retarded tooth movement. Cessation of the medication is likely to be of little benefit due to the protracted half-life of some bisphosphonates, with alendronate having a half-life of 10 years.

While osteonecrosis is a serious potential consequence, it is rare, being more likely with IV administration and prolonged use. Nevertheless, care should be taken to reduce its likelihood.

CASE 1.3

A 45-year-old female presented with osteoporosis. She has been taking oral alendronate. She has a crowded class I malocclusion.

How will her medical history affect her management?

Bisphosphonates pose two major risks to her treatment. There is a very small but serious risk of developing osteonecrosis of the jaws and tooth movement is likely to be difficult. Consequently, informed consent is important prior to embarking on treatment; it is also wise to discuss treatment with the patient's physician. As alendronate has a long half-life, temporary discontinuation is ineffective.

It is wise to avoid invasive procedures, including extractions or temporary anchorage devices. If required, space may be created by transverse or anteroposterior arch expansion or inter-proximal reduction. Alternatively, the goals of treatment can be modified to accept a compromised outcome, obviating the need for extractions and reducing the overall treatment time. In addition, great care should be taken to ensure appliances are smooth and well-fitting, limiting the risk of ulceration and soft tissue trauma. Occasionally, orthodontics is best avoided with a restorative approach being an alternative.

Non-steroidal anti-inflammatory drugs (NSAIDs)

NSAIDs may be used on a long-term basis for chronic illness, including rheumatoid arthritis. They are also recommended for analgesia following manipulation of orthodontic appliances. They act by inhibiting cyclo-oxygenase activity, inhibiting production of prostaglandins. Animal studies have suggested that use of NSAIDs, including aspirin and ibuprofen, for pain control may retard tooth movement (Arias and Marquez-Orozco, 2006). Nevertheless, as their analgesic properties are proven, they continue to have application in orthodontic pain control.

Clinical Examination

Orthodontic treatment planning decisions are governed by both facial and occlusal goals with the aims of optimizing facial harmony and dental aesthetics, and creating a healthy and stable occlusion both in centric relationship and in function. More specifically, treatment planning decisions, including extraction and anchorage requirements, also need to take account of intra-arch features, including degree of crowding, spacing, canine angulation and occlusal curves in relation to the tooth movements planned to achieve the treatment aims. In addition, the influence of inter-arch features in all three spatial planes has a significant bearing on treatment decisions. These features may then be amalgamated in formal space planning to make robust and consistent treatment plans.

Extra-oral examination

The face should be examined both at rest and in animation from the front and in profile. Although absolute measurements can be made and compared to anthropometric means, of more importance are the proportions of component parts relative to each other. Any areas of disproportion should be noted.

What is natural head posture and why is it important?

Natural head posture is the physiological position in which the head is held during normal function. During clinical and cephalometric examination, the orthodontist tries to replicate this using natural head position. This can be reproduced by asking the patient to look straight ahead into the distance,

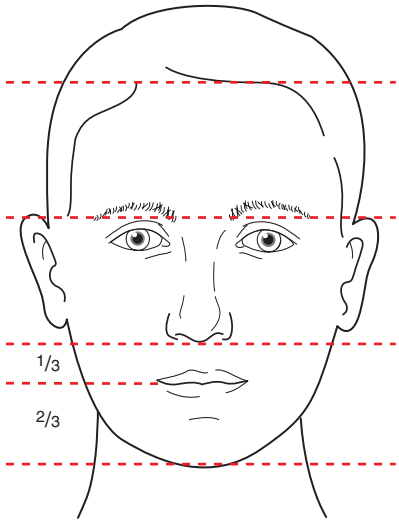

Figure 1.6

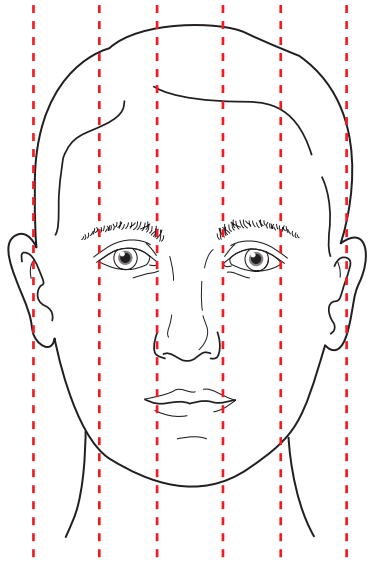

Figure 1.7

or look at themself in a mirror placed in front of them at eye level. Natural head position has been shown to be remarkably reproducible, allowing the orthodontist to compare the soft and hard tissues to an extra-cranial true vertical reference line. This avoids reliance on intra-cranial planes for reference, which are not only subject to significant biological variability but also the same distortion as the facial skeleton in the presence of anomalies of skeletal growth.

Frontal view:

- **Vertically:** The face can be divided into thirds. The lower face can be divided further into thirds with the lower lip making up two-thirds and the upper lip one-third of the total (Figure 1.6).
- **Transversely:** The face can be divided into fifths, with each fifth being approximately the width of the eye (Figure 1.7). Any asymmetry should be noted.

The patient's lips are described as:

- Competent when they meet at rest
- Incompetent when they are apart at rest.

Lip incompetence occurs due to either anteroposterior skeletal discrepancy or increased vertical skeletal proportions. The amount of maxillary incisor display at rest should be approximately 3–4 mm in males and 4–5 mm in females in late adolescence and early adulthood. Incisor show decreases with age, although over 90% of upper lip length is established in females by the age of 7 years (Nanda *et al.*, 1990). Lip competence tends to increase with maturation of the soft tissues and increasing social awareness in adolescence.

What factors contribute to an attractive smile?

Smiling is an integral part of human communication and one of the principal aims of orthodontics is to create a pleasing smile. The patient should therefore be examined in animation during smiling (Sarver, 2001). The three areas that need to be assessed are:

- **Vertical incisor position:** On smiling, most of the upper incisor should be displayed but without excessive gingival display. However, the amount of tooth and gingival display decreases with maturation; this should be borne in mind when examining a younger patient. The gingival contour of the maxillary anterior teeth should also be assessed, the gingival margins of the central incisors and canines ideally being slightly higher than the lateral incisors.
- **Smile width:** The width of the maxillary arch in relation to the lips should be assessed. If the arch is too narrow or set back, the space between the buccal dentition and angle of the mouth, known as the buccal corridor, can be excessive, making the arch look narrow. However, some space to frame the smile is important; otherwise the smile can look artificial. Arch expansion, appropriate torque in the buccal segments, as well as the anteroposterior position of the maxilla relative to the lip drape influence the size of the buccal corridors (Isiksal *et al.*, 2006).
- **Smile arc:** On smiling the incisal edges of the upper anterior teeth should lie on the arc of the lower lip. This is called a consonant smile and is considered

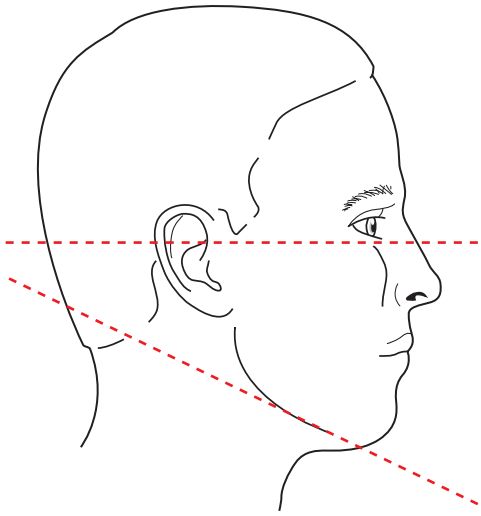

Figure 1.8

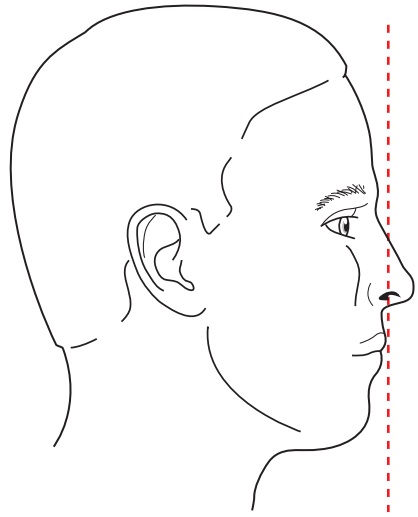

Figure 1.9

the most pleasing (Frush and Fisher, 1958). If the upper anterior teeth follow a straight line, the smile can also look artificial.

Profile view

- **Vertically:** The face can also be divided into equal thirds. The angle between the lower border of the mandible and the Frankfort horizontal plane can be measured with imaginary lines intersecting at the occiput in the presence of a normal vertical relationship (Figure 1.8).
- **Anteroposterior:** The relative position of the dental bases should be described in relation to the cranial base and to each other. These can be visualized by direct palpation or by dropping a vertical line from the forehead through the intersection of the upper lip and base of nose (subnasale) (Figure 1.9). The upper lip should rest on or slightly in front of this line, whilst the chin point should be just behind it. The maxillary dental base should lie approximately 4 mm in front of the mandibular dental base.

The soft tissues of the lower third of the face are described in relation to the relative protrusion of the lips and the angle of the upper lip to the base of the nose, the naso-labial angle. The lips are described as protrusive if they rest in front of a line from the tip of the nose to the chin (Rickett's E-line) (Figure 1.10). With age the lips become less protrusive relative to this line. The naso-labial angle should be between 90 and 110 degrees, although this depends on the shape

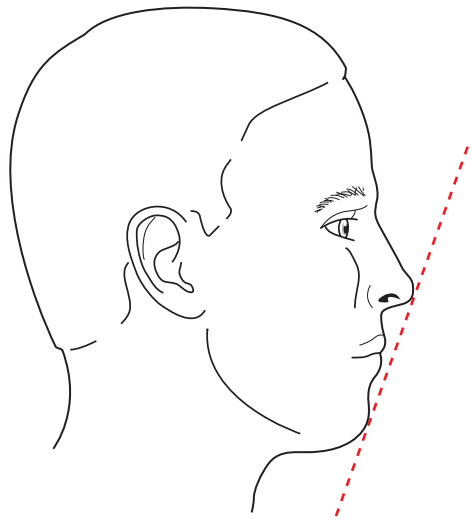

Figure 1.10

of the nose. More practically, the upper lip drape should be parallel to the true vertical previously described (Arnett and Bergman, 1993). Similarly, the labial face of the upper incisors should also be parallel to this line for optimal dental aesthetics.

Temporo-mandibular joints

Both joints should be examined for:

- Clicking
- Crepitus
- Pain
- Locking or limited opening.

What is the relationship between malocclusion and temporo-mandibular joint dysfunction?

Temporo-mandibular joint dysfunction (TMD) is a very common condition in Western societies and its aetiology is considered to be multi-factorial. Certain traits of a malocclusion have been shown in large cross-sectional epidemiological studies to have a weak association with TMD, including anterior open bites, increased overbites, large overjets and posterior crossbites with displacement (Egermark-Eriksson *et al.*, 1983; Mohlin *et al.*, 2007). However, there is no simple relationship. As such, there is no evidence that orthodontic treatment is effective at treating TMD (Luther *et al.*, 2010) and importantly, there is again no evidence that orthodontic treatment induces or exacerbates TMD, including treatment involving extractions (Egermark *et al.*, 2005; Hirsch 2009).

Intra-oral examination

Initial intra-oral examination involves an assessment of dental health. Evidence of active dental disease should be recorded as well as the level of oral hygiene. A plaque index provides an objective score. Each dental arch is then described in isolation and in relation to the opposing arch, both in static and functional occlusion. Key intra- and inter-arch features that should be recorded are outlined below.

Crowding: Dento-alveolar disproportion usually involves a relative excess of tooth tissue, culminating in dental crowding. Crowding has been defined as primary, secondary or tertiary (van der Linden, 1974). Primary crowding refers to an underlying discrepancy of tooth dimension and jaw size. Secondary crowding is caused by environmental factors, including local space conditions in the dental arches and the position and function of the tongue, lips and buccal musculature. Tertiary crowding refers to the propensity for an increase in crowding with dental maturation; imbrication of the lower anteriors in late adolescence and in the third decade is typical.

Crowding can be defined as mild (<4 mm), moderate (4–8 mm) or severe (>8 mm) (Figure 1.11). Crowding is one of a variety of occlusal traits that has implications for orthodontic space requirements and treatment planning. To relieve crowding, treatment protocols that could be considered include dental extractions, typically of premolars; transverse expansion; antero-posterior arch lengthening, either by distal movement

Figure 1.11

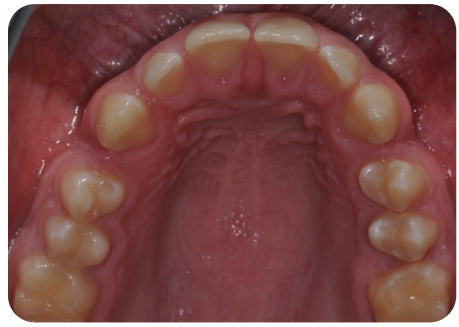

Figure 1.12

of the posterior teeth or advancement of the anteriors; or inter-proximal reduction.

Severe crowding usually warrants extractions as part of the orthodontic treatment plan, relieving crowding while facilitating placement of the dentition in a stable soft tissue environment. Extractions are also considered with moderate degrees of crowding, while mild crowding is usually dealt with without extractions if possible, depending on the proposed final position of the labial segments.

Spacing: Spacing is less common than crowding. It may be generalized (Figure 1.12) or local. Physiological spacing tends to occur between the maxillary central incisors during development; a maxillary median diastema and tends to close upon eruption of the maxillary canines. In approximately 8% of individuals, this persists into the permanent dentition (Keene, 1963). It may be closed with fixed appliances, although there is a premium on prolonged fixed retention to retain this correction.

Generalized spacing may be a manifestation of relatively large dental bases, with normal tooth size and shape being more common in Afro-Caribbeans (Richardson *et al.*, 1973; Mugonzibwa *et al.*, 2008).

Occasionally, spacing may reflect reduced tooth number, size and width. Missing and diminutive maxillary lateral incisors are a common finding. Relocation of space following treatment may be necessary to facilitate build-up of these teeth, improving dental aesthetics and long-term stability (Figure 1.13).

Rotations, contact point displacements and labio-lingual displacements: Rotations and displacements of teeth should be recorded. Correction of rotations in the buccal segments will generate space as rotated premolars and molars occupy more space than aligned teeth; the reverse is true in the anterior dentition.

Figure 1.13

Canine position and angulation: Particular note should be made of the position of the maxillary canines, even if unerupted. Maxillary canines should be palpable buccally from 8 to 10 years. If this is not the case, it may indicate canine ectopia warranting further investigation.

The angulation of erupted canines has implications for anchorage management. The canines have long and broad roots; significant change in the position of their roots is therefore anchorage demanding. The desired final canine position involves slight mesial positioning of the crown relative to the root (mesial angulation); therefore, correction of distal canine crown angulation necessitates a significant bodily root movement. This should be considered when planning extractions and requirements for anchorage support.

How would you classify the crowding in the maxillary arch in the intra-oral records shown in Figure 1.14?

The maxillary arch is moderately crowded; there is approximately 7 mm of crowding.

What do you notice about the maxillary canines? What is the clinical relevance of this?

Both maxillary canines are distally angulated. The anchorage requirement in the maxillary arch is

Figure 1.14

increased as there are likely to be significant reciprocal forces during attempted distal root movement of both canines.

What do you think of the mesio-distal width of the maxillary lateral incisors? What is the clinical relevance of this finding?

The mesio-distal width of both maxillary lateral incisors is reduced. Both teeth will require build-up to restore ideal dental aesthetics and occlusal harmony. If a decision is made to avoid build-up of these teeth, either a reduced overjet and overbite will result or inter-proximal reduction of the lower anteriors could be performed to eliminate the inter-arch tooth-size discrepancy.

Incisor inclination: Labial segment inclination is the inclination of the maxillary and mandibular incisors relative to the dental bases. Incisors may be upright, proclined or retroclined. The inclination of the anterior teeth represents the influence of soft tissue relationships on the dentition. The teeth are held in soft tissue equilibrium by the lips and cheeks externally and the tongue on the inside. Mismatch in the soft tissue forces acting on the teeth may result in changes in incisor inclination. In Figure 1.14, the maxillary central incisors have been retroclined, almost certainly by a high lower lip line. In Figure 1.15, incisor proclination has occurred as a result of a lip trap. Furthermore, incisor inclination may compensate for a skeletal discrepancy. Typically, retroclination of the maxillary incisors tends to occur in the presence of a milder skeletal class II pattern (Figure 1.14), whilst proclination is more common with a more severe class II discrepancy (Figure 1.15). In contrast, mandibular incisor retroclination is often seen in association with a skeletal class III discrepancy; this also occurs under soft tissue influence (Figure 1.16).

Curve of Spee: The curve of Spee is an imaginary line formed in the sagittal plane between the cusp tips of the mandibular first molars and incisors. An increased curve represents a deeper curve with relative inferior positioning of the mandibular premolars; this is associated with increased overbite. To reduce the depth of this curve, space is required (Germane *et al.*, 1992). Rarely a reversed curve of Spee may be seen; this is associated with reduced overbite or anterior open bite.

Occlusion (inter-arch features): The static and functional occlusion should both be described, with the static occlusion recorded in three spatial planes. Sagittal relationships, including molar, canine and

Figure 1.16

Figure 1.15

incisor relationships, and overjet should be recorded. These terms are defined as follows:

- **Molar relationship** (Angle's classification):
  - **Class I:** The relative position of the dental arches is normal, with first molars in normal occlusion; the mesio-buccal cusp of the upper first permanent molar occludes in the mid-buccal groove between the mesial and distal buccal cusps of the lower.
  - **Class II:** The relationship of the dental arches is abnormal; the mandibular teeth occlude distal to normal. Angle recognized two subdivisions under class II:
    Class II division 1 is characterized by protruding upper incisors
    Class II division 2 is characterized by lingually inclined upper incisors.
  - **Class III:** The relationship of the dental arches is also abnormal, with mandibular first molars occluding mesial to the Class I position.
- **Incisor relationship.** This is described using the British Standards Institute Glossary of Dental Terms:
  - **Class I:** The mandibular incisor tip occludes or lies on or below the cingulum plateau of the maxillary incisors.
  - **Class II:** The mandibular incisor tip occludes or lies posterior to the cingulum plateau of the maxillary incisors. This classification is further subdivided into:
    Class II division 1: The overjet is increased with upright or proclined maxillary incisors
    Class II division 2: The maxillary incisors are retroclined, with a normal or occasionally increased overjet.
  - **Class III:** the mandibular incisor tip occludes with or lies anterior to the cingulum plateau of the maxillary incisors.

Overjet is measured from the labial surface of the most prominent maxillary incisor to the labial surface of the mandibular incisors. If there is an anterior crossbite the overjet is given a negative value.

The aim of comprehensive orthodontic treatment invariably involves creating a class I incisor relationship with an overjet of 2–4 mm. With an intact dentition and correct inclination of the anterior dentition, this also necessitates class I molar and canine relationships. However, in certain malocclusions, class II or III molar relationships may be accepted with removal of maxillary premolars or mandibular premolars, respectively, camouflaging the incisor relationship and also achieving class I canine relationships bilaterally. Therefore, if the molar relationships deviate from class I, the treatment plan will revolve around the decision to either correct the molar relationships to class I or to accept the molar relationship but camouflage the malocclusion with single-arch extractions.

Class II molar relationships may be corrected by distal movement of the maxillary molars, mesial movement of the mandibular molars or more often a combination of these approaches. Methods to correct class II molar relationships include headgear, functional appliances, temporary anchorage devices (TADs) and class II correctors, e.g. Forsus springs. Differential extractions with removal of maxillary first premolars and mandibular second premolars also promote molar correction and overjet reduction in class II malocclusion. In a non-growing patient with severe mandibular retrognathia, a mandibular advancement osteotomy may be required to correct the incisor and molar relationships.

Class III molar relationships may be addressed in growing patients using protraction headgear or class III functional appliances. Differential extractions, typically loss of maxillary second premolars and mandibular first premolars, and inter-arch class III elastic may be used to correct class III molar relationships, promoting establishment of a positive overjet and overbite. In non-growing patients in the presence of a severe skeletal class III base relationship, orthognathic surgery may be required.

In class II malocclusions, extraction of maxillary premolar units can be carried out in isolation, accepting the class II molar relationship (Figure 1.17). This

Figure 1.17

approach facilitates correction of the canine relationship; limited controlled advancement of the mandibular incisors may also be planned, reducing the anchorage requirement to reduce the overjet. Conversely, in class III malocclusion, a decision may be made to remove mandibular premolars only to retract the mandibular incisors, maintaining the antero-posterior position of the maxillary incisors. While the aim is to correct both incisor and canine relationships to class I, class III molars would be accepted.

Transverse relationships: Transverse discrepancy should be noted using the following descriptions:

- Buccal crossbite: Buccal cusps of the maxillary dentition occlude palatally to the buccal cusps of the mandibular dentition
- Lingual crossbite: Palatal cusps of the maxillary dentition occlude buccally to the buccal cusps of the mandibular dentition (this can also be referred to as a scissors bite)
- Unilateral crossbite: Affects one side of the dental arch
- Bilateral crossbite: Affects both sides of the dental arch.

Teeth in crossbite should be recorded along with any associated displacement that may exist on the mandibular arc of closure from retruded contact position (RCP) to inter-cuspal position (ICP). If there is a displacement, its location and magnitude should be recorded.

Correct transverse arch co-ordination facilitates occlusal inter-digitation, function and aesthetics. Occlusal displacements, which are often related to crossbites, may be associated with occlusal and gingival trauma and have been weakly linked to temporo-mandibular dysfunction. While correction of crossbites without associated displacement is not essential, this will usually be an aim of comprehensive orthodontics. Crossbite correction may require either maxillary arch expansion, with fixed or removable appliances; mandibular arch constriction, often with extractions; or a combination of both approaches. Arch constriction is thought to be more stable than expansion and may also be encouraged by addition of lingual crown torque to the lower dentition. Conversely, lingual crossbite (scissors bite) correction may be reliant on maxillary arch constriction and broadening of the mandibular arch.

Vertical relationships: Overbite is the vertical overlap of the lower incisors by the maxillary incisors with the teeth in occlusion. Normal overjet is characterized by vertical overlap of one-third to one-half of the mandibular incisors.

Overbite may be:

- **Increased** if the maxillary incisors overlap the mandibular incisor crowns vertically by more than one-half of the lower incisor crown height
- **Decreased** if the maxillary incisors overlap the mandibular incisors by less than one-third of the lower incisor crown height
- **Complete** if there is contact between the mandibular incisor edges (or maxillary if there is a class III incisor relationship) and the opposing dentition or mucosa
- **Incomplete** if there is no contact between the mandibular incisor edges (or maxillary if there is a class III incisor relationship) and the opposing dentition or mucosa
- **Traumatic** if there is evidence of trauma to either the palatal mucosa or to the gingivae of the lower labial segment.

Traumatic overbite is most common in class II division 2 malocclusion and may be compounded by poor oral hygiene resulting in gingival inflammation and attachment loss (Figure 1.18). Overbite reduction may be achieved by intrusion and proclination of the incisors, extrusion of the posterior teeth or by both mechanisms. While overbite reduction carries a space

Figure 1.18

requirement to level an increased curve of Spee, lower arch extractions are often best avoided as these may complicate overbite reduction.

Anterior open bite is a vertical gap between the maxillary and mandibular incisors with the teeth in the ICP. The distance between the incisal edges and the posterior extent of the open bite should be recorded. Overbite may be increased using auxiliaries such as occipital pull headgear, intrusion splints and temporary anchorage devices, as well as specific mechanics, e.g. Kim mechanics. Extractions may also be beneficial with resultant space facilitating retraction, extrusion and uprighting of the anterior dentition. In addition, mesial movement of the buccal segments may allow increase in the overbite (Sarver and Weissman, 1995).

What are Andrews's six keys of normal occlusion?

Lawrence Andrews, based in San Diego, noted that many treated cases, despite having an Angle class I molar relationship, did not have an ideal buccal segment inter-digitation. Andrews (1972) came to this conclusion following assessment of 120 dental study casts of individuals who had not undergone orthodontic treatment and who had normal occlusions. From these he described six keys of normal occlusion:

1. **Molar relationship:** The distal surface of the disto-buccal cusp of the upper first permanent molar makes contact and occludes with the mesial surface of the mesio-buccal cusp of the lower second molar. The mesio-buccal cusp of the upper first permanent molar lies in the groove between the mesial and middle cusps of the lower first permanent molar.
2. **Crown angulation or mesio-distal tip:** The gingival portion of the long axis of each crown is distal to the incisal portion.
3. **Crown inclination:** Labio-lingual or bucco-lingual inclination. The upper and lower anterior crown inclination is sufficient to resist over-eruption of the anterior teeth and to allow proper distal positioning of the contact points of the upper teeth in relation to the lower teeth, permitting proper occlusion of the posterior crowns. A lingual crown inclination exists in the upper posterior crowns, is constant and similar from canines through to the second premolars, and slightly more pronounced in the molars. For the lower posterior teeth, the lingual crown inclination progressively increases from canines through to second molars.
4. **Rotations:** There are no rotations.
5. **Spaces:** There are no spaces, contact points are tight.
6. **Occlusal plane:** The plane of occlusion is either flat or there is a slight curve of Spee.

Space planning

Formal space planning involves assimilation of both intra-arch features and inter-arch relationships to produce an overall space requirement to justify treatment and extraction decisions. Furthermore, space planning may help to determine anchorage requirements and treatment mechanics. The Royal London Space Plan involves integration of these features, assigning specific space requirements to each aspect of the malocclusion (Kirschen *et al.*, 2000a,b), including change in the sagittal position of the incisors; crowding or spacing; changes in arch width; occlusal curves; and torque and angulation changes.

What factors contribute to the space requirement in Figure 1.14?

Maxillary arch

- Crowding (7 mm)
- Torque requirement: 10 degrees of torque is required to the maxillary incisors; 2 mm of space is needed to achieve this
- Requirement for build-up of the UR2 and UL2. Both lateral incisors are 4 mm in width; 1.5 mm would be required per tooth if space opening is chosen

Mandibular arch

- Crowding (2 mm)
- Arch levelling: the curve of Spee is 3 mm deep; 1 mm of space will be required to reduce this

What treatment plan would you suggest based on this space analysis?

The space requirement in the maxillary arch is 12 mm if build-up of the lateral incisors is planned. However, just 3 mm of space is required to achieve the treatment goals in the mandibular arch. Hence, consideration could be given to removal of both maxillary first premolars, treating the mandibular arch on a non-extraction basis. If maxillary first premolars alone are extracted, only 1 mm of mesial maxillary molar movement is permissible bilaterally, and consideration should be given to anchorage support in the upper arch.

Functional occlusion

Based on the concepts of a mutual protective functional occlusion, the following features should be recorded:

- Canine guidance or group function in lateral excursion
- Presence of non-working side interferences
- Large discrepancies between the RCP and ICP, particularly in the presence of crossbite.

Diagnostic summary

At the end of the clinical examination a short diagnostic summary should be produced containing the salient points ascertained from the interview and examination (Box 1.1).

BOX 1.1 KEY DIAGNOSTIC FEATURES

Name
Age and sex
Medical history
Referral source
Patients concerns and motivation

Extra-oral

Skeletal relationship:	
Antero-posterior	
Vertical	FMPA
	Lower face height
Transverse	Facial symmetry
Soft tissues	Lip competence
	Lip lengths
	Naso-labial angle
Upper incisor show	At rest
	Smiling
Temporo-mandibular joint	

Intra-oral

Teeth present	
Dental health (restorations, caries)	
Oral hygiene – periodontal	
Lower arch	Crowding
	Incisor inclination
	Curve of Spee
Upper arch	Crowding
	Incisor inclination
Occlusion	Incisor relationship
	Overjet
	Overbite
	Molar relationship
	Canine relationship
	Centre lines
	Functional occlusion
	Other features

Radiographic Analysis

Following clinical assessment, radiographic analysis is usually warranted. A panoramic view is indicated prior to instituting orthodontic treatment to assess the presence and position of unerupted teeth, and root length and morphology.

What are the potential shortcomings associated with a panoramic view?

- **Lack of sharpness:** Due to various factors including ghost imaging, summation images, static distortion and processing errors.
- **Horizontal distortion:** This tends to be non-linear.
- **Vertical distortion:** Believed to be twice as severe as horizontal distortion.
- **Superimposition of the cervical spine.**
- **Limited focal trough:** Lingually-positioned roots falling outside the focal trough are usually magnified. Similarly, excessively inclined teeth not contained within the boundaries of the focal trough may appear narrow or foreshortened on the resultant image. Consequently, the anterior region of the orthopantomogram may be unrepresentative; reliability may be complicated further by inaccurate patient positioning within the machine.

Therefore, panoramic radiography can be supplemented with intra-oral views to provide greater detail, particularly in the maxillary anterior region. Furthermore, intra-oral views, including peri-apical radiographs and occlusal views (Witcher *et al.*, 2010), may highlight the position of unerupted teeth using the parallax technique.

Cephalometric analysis

A cephalometric radiograph is taken in a standardized and reproducible manner using a cephalostat, which orientates the subject at a fixed distance from the X-ray tube and film during the exposure. This means that image magnification is constant for each individual machine, which allows the direct comparison of cephalometric views taken of one individual at different time points or between individuals. The most common view used in orthodontics is the cephalometric lateral skull radiograph, although occasionally postero-anterior views of the skull are taken to aid in the diagnosis of facial asymmetries or the localization of impacted teeth.

This section describes a simple and easily applied analysis for a cephalometric lateral skull radiograph that can be used to supplement the clinical examination.

A simple cephalometric analysis and mean Caucasian values

SNA	[81]
SNB	[78]
ANB	[3]
SN Mx	[8-11]
Wits Appraisal	[0-1]
FMA	[27]
MMPA	[27]
UI Mx	[109]
LI Md	[93]
Interincisor Angle	[135]
LI to APo	[2]
Upper lip E-plane	[-4]
Lower Lip E-Plane	[-2]
Nasolabial Angle	[108]
TAFH	[119]
UAFH	[54]
LAFH	[65]
% LAFH	[55]

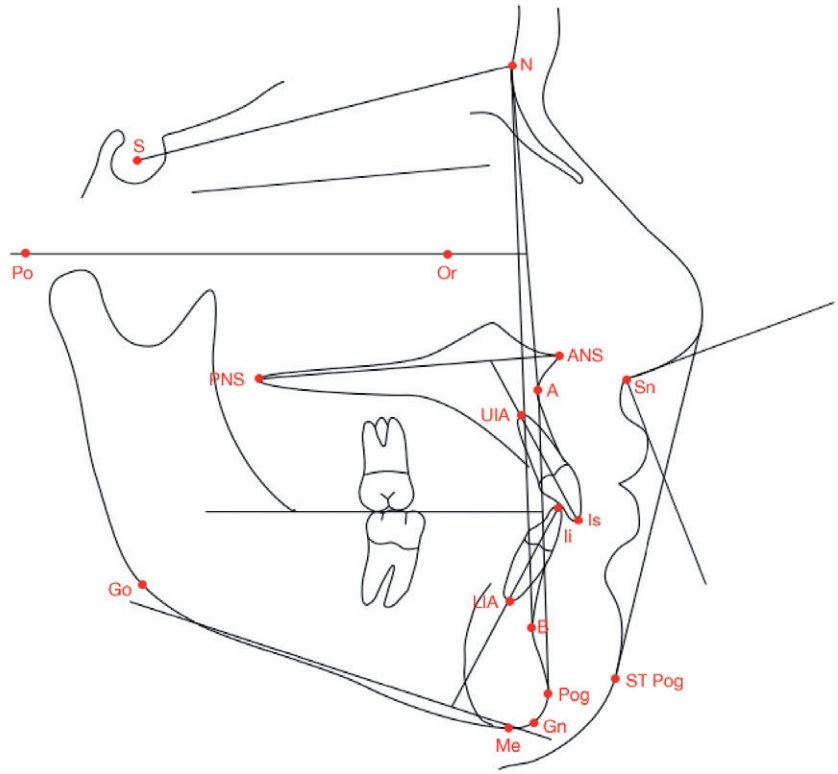

Figure 1.19

The analysis provides useful numerical information on the skeletal base relationship, position of the dentition within the face and the soft tissue profile. This aids in understanding the aetiology of a malocclusion and therefore is a valuable component of diagnosis and treatment planning. In addition, cephalometrics can be used as a definitive measurable baseline record to monitor treatment progress and growth by superimposition of serial radiographs.

When should a cephalometric radiograph be taken?

A cephalometric lateral skull radiograph should not be taken routinely on all patients. The decision can be justified in a number of circumstances, but this view is normally recommended if treatment of the malocclusion will involve:

- Significant anterior or posterior incisor movement
- Correction of a skeletal discrepancy with growth modification or orthognathic surgery
- Monitoring, or possible early interventional treatment in a young patient for a marked skeletal discrepancy.

A simple cephalometric analysis is described for routine orthodontic cases (Figure 1.19). The component cephalometric points, constructed lines and both angular and linear measurements are described. Mean Caucasian values are also provided.

Cephalometric landmarks

A number of hard and soft tissue cephalometric points need to be identified on the cephalometric lateral skull radiograph prior to applying an analysis (Box 1.2). These form the basis of construction for the relevant lines and planes, and allow the appropriate linear and angular measurements for the chosen analysis to be made.

The following points provide the basis for a simple analysis:

BOX 1.2 CEPHALOMETRIC HARD AND SOFT TISSUE LANDMARKS

Sella (S)	Midpoint of sella turcica (= posterior limit of the anterior cranial base)
Nasion (N)	Most anterior point on the fronto-nasal suture (= anterior limit of the anterior cranial base)
A point	Deepest point on the curved profile of the maxilla between the anterior nasal spine and alveolar crest (= anterior limit of the maxillary skeletal base and forms the superior landmark for construction of the A–Po line)
B point	Deepest point on the curved profile of the mandible between the chin and alveolar crest (= anterior limit of the mandibular skeletal base)
Porion (Po)	Uppermost and outermost point on the external auditory meatus (= posterior landmark for the Frankfort plane)
Orbitale (Or)	Most inferior and anterior point on the orbital margin (= anterior landmark for the Frankfort plane)
Gnathion (Gn)	Most anterior and inferior point on the chin
Menton (Me)	Most inferior point of the mandibular symphysis in the midline (= anterior landmark for the mandibular plane)
Pogonion (Pog)	Most anterior point on the chin (= inferior landmark for the A–Po line)
Gonion (Go)	Most posterior and inferior point on the angle of the mandible (= posterior landmark for the mandibular plane)
Posterior nasal spine (PNS)	Tip of the bony posterior nasal spine in the midline (= posterior landmark of the maxillary plane)
Anterior nasal spine (ANS)	Tip of the midline bony anterior nasal spine (= anterior landmark for the maxillary plane)
Incisor superius (Is)	Tip of the crown of the most anterior maxillary central incisor (= lower landmark for maxillary central incisor long axis)
Upper incisor apex (UIA)	Apex of the most anterior maxillary central incisor root (= upper landmark for the maxillary central incisor long axis)
Incisor inferius (Ii)	Tip of the crown of the most anterior mandibular central incisor (upper landmark for mandibular central incisor long axis)
Lower incisor apex (LIA)	Apex of the most anterior mandibular central incisor root (= lower landmark for mandibular central incisor long axis)

The soft tissue profile should also be traced and the following points identified:

Subnasale (Sn)	The point of intersection between the nasal septum and upper lip along the mid-sagittal plane
Soft tissue pogonion	Most anterior point on the soft tissue chin

Skeletal base relationships

The antero-posterior and vertical skeletal relationship can be measured on a cephalometric lateral skull radiograph (Box 1.3).

Antero-posterior skeletal base relationship: The antero-posterior relationships of the maxilla and mandible are assessed in relation to the anterior cranial base by measuring the SNA and SNB angles. A significant increase in these values when compared to population norms can indicate maxillary or mandibular protrusion (prognathia) relative to the anterior cranial base; whilst a reduction is indicative of retrusion (retrognathia).

The subtracted difference between the SNA and SNB angle (the angle ANB) will give an indication of the antero-posterior relationship between maxilla and mandible:

- ANB = 2–4 degrees: Skeletal class I
- ANB >4 degrees: Skeletal class II
- ANB <2 degrees: Skeletal class III.

BOX 1.3 WHAT DIAGNOSTIC INFORMATION CAN BE OBTAINED FROM A CEPHALOMETRIC ANALYSIS?

SNA — Position of the maxilla in relation to the anterior cranial base

SNB — Position of the mandible in relation to the anterior cranial base

ANB — Relative position of maxilla and mandible in relation to the anterior cranial base:
- Values <4 degrees indicate a class II relationship
- Values >2 degrees indicate a class III relationship

This therefore confirms the skeletal discrepancy

MMPA — Vertical relationship of the maxilla and mandible:
- Increased MMPA value (high angle) cases are associated with posterior growth rotation, which results in a tendency towards a reduced overbite or anterior open bite. In a growing individual this suggests that the overbite may reduce with further growth. There is often more rapid space loss in high angle cases and it is sensible to avoid extrusive mechanics during treatment as these may reduce the overbite further.
- Reduced MMPA value (low angle) cases are associated with anterior growth rotations. These are more associated with increased overbite, which may worsen with future growth. In these cases there may be difficulty with space closure during treatment, which can indicate treatment on a non-extraction basis.

UI Mx — Inclination of upper central incisors to the maxillary plane:
- The inclination of the upper incisor teeth can illustrate an existing compensation for a skeletal discrepancy. For example, class III cases can be associated with retroclined lower incisors and proclined upper incisors in the presence of a class III skeletal pattern. An increase in inclination of the upper incisors classifies the incisor position as being proclined. In clinical practice this may alter treatment mechanics based on the need to improve the inclination of the upper incisors. For example, in a case being treated with a functional appliance where the upper incisors are proclined, a labial bow may be incorporated in the appliance design to retrocline the upper incisors.
- When the upper incisors are of average inclination in the presence of a skeletal class II pattern, this may indicate the need for bodily retraction during treatment to avoid excessive retroclination.
- In class II cases where the upper incisors are retroclined (class II division 2 cases) this indicates a need for palatal root torque (which is anchorage demanding) during treatment.
- Where the upper incisors are retroclined in class III cases, this may indicate some scope to procline the upper incisors during treatment and camouflage the skeletal discrepancy.

LI Md — Antero-posterior position of the lower incisors is important during treatment planning
Changes in inclination of the lower incisors as a result of treatment are thought to affect stability
Lower incisor inclination can also reflect the presence of dento-alveolar compensation

A-Pog — Pleasing facial aesthetics
Stability of antero-posterior lower incisor position

Measuring jaw position in relation to the anterior cranial base can be problematic because alterations in the SN plane caused by erroneous positions of either sella or nasion can influence the SNA and SNB values. If the position of nasion is at fault, this will also influence ANB. The **Eastman correction** is available to overcome this:

- For every degree SNA is greater than 81 degrees, 0.5 degrees° should be subtracted from the ANB value
- For every degree SNA is less than 81 degrees, 0.5 degrees should be added to the ANB value.

This correction for ANB can only be applied for changes in the position of nasion, which is indicated by a SN–maxillary plane within the normal range of 8 ± 3 degrees.

An SN–maxillary plane value outside this range indicates that the position of sella is at fault. Because this affects the SNA and SNB values to the same extent, the ANB value does not require correction.

However, the Eastman correction is associated with some overestimation of the true values as nasion moves both anteriorly and posteriorly in relation to

sella and therefore, should only be used as a very approximate guide (Kamaluddin *et al.*, 2011).

To avoid errors associated with discrepancies of the position of the cranial base within the skull it is advisable to carry out an additional analysis that is independent of this region. This is easily achieved by using the **Wits appraisal of jaw disharmony**. This relates the jaws to the functional occlusal plane (FOP, which passes through the occlusion of the first permanent molars and premolars) via perpendicular lines drawn from A point and B point (AO and BO, respectively):

- For boys, BO should lie 1 mm ahead of AO in a class I relationship
- For girls, BO and AO should be coincident in a class I relationship.

Thus, a class II relationship is associated with AO being positioned ahead of BO for both sexes. A class III relationship occurs in boys when BO is positioned greater than 1 mm ahead of AO, whilst for girls any position of BO ahead of AO is class III. It should be remembered however, that there is error associated with locating the functional occlusal plane, which can lead to some inaccuracy in assessing the jaw relationship using this method.

Vertical skeletal base relationship: The vertical relationship between maxilla and mandible can be assessed by angular measurement and in relation to the face using linear values.

The maxillary–mandibular planes angle (MMPA) provides a useful angular measurement of the vertical jaw relationship. The maxillary plane is represented by a line constructed through ANS–PNS, whilst the mandibular plane is constructed using a line through Go–Me. The mean value of the MMPA is 27 ± 5 degrees. An alternative value is the Frankfort–mandibular plane angle (FMPA), with the Frankfort plane constructed as a line through Or–Po and this should also be 27 ± 5 degrees.

The upper and lower anterior face heights provide a linear measurement of face height and their ratio provides an indication of vertical facial proportion. The total anterior face height (TAFH) is measured from nasion to menton (mean value = 119 mm). The upper anterior face height (UAFH) extends from nasion to ANS (mean value = 54 mm), whilst the lower anterior face height (LAFH) is measured from ANS to menton (mean value = 65 mm). The LAFH should be approximately 55 ± 2% of the TAFH when measured cephalometrically.

Dental analysis

The position of the upper and lower incisors can be measured on a cephalometric lateral skull radiograph, both in relation to the individual jaws, the lower third of the face and to each other.

Incisor inclination: The upper and lower incisor inclinations are measured to the maxillary plane (UI Mx = 109 ± 6 degrees) and mandibular plane (LI Md = 93 ± 6 degrees), respectively.

Lower incisor inclination can be influenced by the mandibular plane angle, with an increase in this value being associated with retroclination and a decrease with proclination. A simple compensation can be applied to obtain the ideal lower incisor inclination for a particular mandibular plane angle by subtracting the MMPA value from 120 degrees.

Lower incisors: The position of the mandibular incisors within the face is often used as an aid to treatment planning. A relatively quick and simple means of assessing this is provided by measuring the distance of the lower incisor tip to a line constructed from A point to pogonion (A-Pog). In a well-balanced face the lower incisor edge should be approximately 1 mm (±2) ahead of A-Pog.

Inter-incisal angle: The inter-incisal angulation (UI–LI) should also be measured and has a mean value of 133 ± 10 degrees.

Soft tissue analysis

A multitude of soft tissue analyses have been described but two useful and relatively simple measurements are provided by the naso-labial angle (NLA) and Ricketts' Esthetic-line (or E-line).

- The NLA is formed at the intersection of a line extending from the subnasale tangent to the columella of the nose and upper lip. The average value is 110 ± 10 degrees.
- The E-line extends from the nasal tip to the soft tissue pogonion. Both lips should be behind this line, the upper by around 4 mm and the lower 2 mm.

Both of these relationships can be unduly influenced by morphology of the nose. The distance of the lips to the E-line is age-related, with both tending to become more retrusive with age. However, together they provide a useful assessment of lip position within the facial profile and supplement the antero-posterior skeletal analysis.