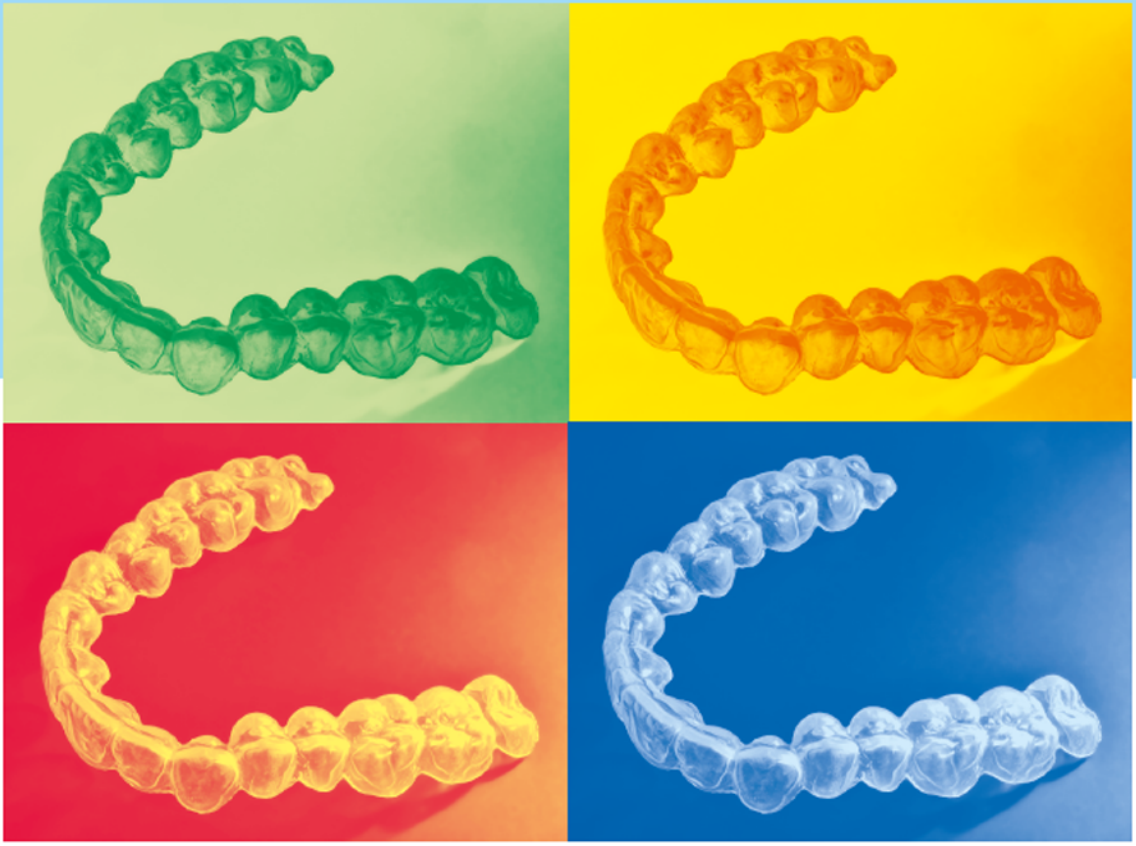
Orthodontic Aligner Treatment

A Review of Materials, Clinical Management, and Evidence

Theodore Eliades
Athanasios E. Athanasiou



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Contents

Foreword

Over time, changes in the armamentarium of orthodontics are "invented" and offered up to the profession. Some of these changes are described as new and improved; some are also termed "game changers" and are broadly disseminated and widely advertised in that tone. However, many of these changes in the appliances and strategies of orthodontics are not new at all, they do not produce a significant improvement that can be demonstrated, and most of these advancements do not endure. On the other hand, some changes do improve our knowledge and patient care, and they result in an important, obvious, and enduring change. For example, one of the last big changes that has occurred in orthodontics was confirmed by the disappearance of the dark room; everyone had one and now they are being repurposed or disappearing from the typical office design. Of course, this affect was produced by the real change—improvements in patient imaging.

This book highlights another invention that has and is changing orthodontics, and that is well appreciated by all of orthodontics: treatment with a series of plastic aligners. This development is not new at all in that it was first discussed by Kesling in the 1940s. He suggested that a series of removable rubber-like "positioners" could be used to treat a malocclusion to a planned result. Perhaps, due to patient or practitioner resistance, his efforts did not produce the desired change in orthodontics, but his ideas continued. Fast forward in time, through inquiry to refinement by the likes of Sheridan, Hilliard, Nahoum, Ponitz, McNamara, Rinchuse, Boyd, and many others, include developments in materials (importantly thermoforming plastics), technical advancements in computer hardware and software notably intraoral scanners and computer-aided design/computer-aided manufacturing (CAD/CAM), and the bedrock for a significant change in orthodontic treatment had been laid.

So, as the century turned, Chishti and Wirth (former orthodontic patients) began the planning and development of a new and clear aligner approach and in 2000 started marketing the Invisalign System. Through a computerized model, a plan was constructed that intended to move teeth from the initial malocclusion to the desired result via a series of clear aligners. But, because this approach was clearly different from traditional orthodontic approaches, practitioners resisted aligner treatment at first. Likewise, educational institutions did not hasten to teach this new technique; in some schools, it was banned. Practitioners who did adopt the technique and presented their experiences were severely criticized. Also, academics that performed research on the approach were sometimes ostracized.

So, now two decades later, one could ask "Where are we now?" First of all, there are many more companies that offer aligners. Most schools teach the technique, many practitioners have incorporated the technique in their practices, and individuals who have knowledge and experience with aligners are popular speakers and teachers. But, best of all, the public is very interested and they seek it out in this form of orthodontic treatment.

At this point, one can conclude that aligner treatments are here to stay and will continue to be of interest to all of orthodontics as the technique continues to improve and mature. Better information regarding aligner treatment will continue to increase through proper research and via presentations, journals, and textbooks.

So, what's the next big advancement? To that inquiry, I would argue that this book answers the question; it is the next advancement. Sure, there are already some books on aligner treatment, but for the most part those books are "How To" books; few, if any, describe aligner treatment as does this book. In this book, the topic at hand is discussed on the basis of experience and evidence, and that is its strength.

The book itself is logically separated into chapters that address the main topics of the subject, and the authors represent a global perspective and in many ways demonstrate their area of inquiry and depth of experience and expertise. The authors are knowledgeable, honest, and accurate, and it is clear that they respect the scientific perspective.

The chapter topics are important and cover the subject as it is known and appreciated at the present time. They address the benefits and drawbacks of aligner treatment, the materials involved, case selection, limitations by age and type of malocclusion, and patient reaction to the treatment. But there is much more—as you will find out.

Clinicians must have an understanding of biomechanics, materials, biology, periodontal response, occlusion, etc., to properly use this treatment. And, as always is the case, the practitioner's ability to formulate a high-quality diagnosis and treatment plan is paramount. But, if clinicians do possess these characteristics when using aligners, orthodontic knowledge increases, treatment improves, and patients are better served.

What's next? Sooner rather than eventually the teeth will be scanned in the orthodontist's office, digital tooth movement planning will be accomplished in the orthodontist's office, and the necessary aligners will be printed in the orthodontist's office. Many practitioners are not far from this now. We will all notice these things are occurring as time goes on. But, like the disappearance of the dark room, we may notice something ancillary as well—like the disappearance of alginate or a constriction in many companies that manufacture aligners.

The cost of this book and the time necessary to read it will be an excellent investment in terms of increasing your knowledge, ability, skills, and service to others. Pay attention to this book; you will not regret it.

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Preface

With the expansion of adult orthodontic treatment in the 1980s, the use of minimally visible appliances became a high priority, which could not be satisfied by ceramic or plastic brackets. The need to develop clear or "invisible" orthodontic appliances led to the development of removable, thermoplastically formed appliances which apply forces to teeth based on a predetermined strain. As result of this development, new treatment philosophy and technique of the clear aligner was introduced, stretching the functional ability of these appliances to their limits by incorporating more treatment types in managing different malocclusions of various age groups.

The initial systems featured a case planning and execution of a planned series of orthodontic tooth movements outside the control of the clinician. This made the orthodontic community skeptical about the generalized, large-scale application of these systems to routine practices but, on the other hand, boosted the treatment provided by nonspecialist practitioners. With the commercial patents expiring, the systems made available by different companies to clinicians expanded and a wide spectrum of aligner types are currently available, with some allowing for an in-office management of treatment planning and aligner fabrication.

The attractiveness of aligners to the esthetically conscious adult and adolescent patients expanded their use. As a result, orthodontic postgraduate programs gradually incorporated these systems in their curricula to cover a gap of training for the graduating specialists who previously had to rely largely on the educational material and instructions of dental industry to cover their needs on this technique. This, in turn, initiated the need to depart from the previously followed substantiation of treatment through a series of case presentations, anecdotal evidence, expert opinions, and other low-quality scientific evidence and include robust data analysis from designed studies on the topics of outcome assessment, undesirable effects, and other parameters of treatment such as duration, oral microbiota changes, and forces generated by aligners.

There is a discrepancy between the advanced, rapid pace of developments in the field of clear aligner orthodontic therapy and the status of relevant scientific documentation and evidence. The book reviews the subject from clinical, technical, materials, and treatment outcome perspectives, emphasizing on the principles and evidence of aligner treatment. It also includes a clinical manual, case presentations, and tips on various applications of aligner treatment in adolescents and adults to be used by the reader. As such, it serves as a reference source of the aligner technique with many different systems. It also includes the most recent guidelines on clinical management with aligners and presents the evidence in a variety of fields. This extends from material properties, to assessment of treatment outcome, to forces generated with aligners. This book also provides a detailed list of case planning with aligner systems for a wide spectrum of malocclusions.

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Section I

Introduction: Types and Material Properties

I

1 Aligner Treatment: An Overview*

Lauren Teske†, T. Gerard Bradley, and Sarandeep S. Huja

Summary

For almost 20 years, clear aligners have been used with growing popularity in addressing with success patients' demands for esthetic orthodontic treatment. Many companies all over the world have developed methods of fabricating custom-made clear aligners designed to gradually and sequentially move teeth to their desired positions. Treatment efficacy with clear aligners has been reported to be good but further investigation of the various aspects of this kind of orthodontic treatment modality is needed for scientific evidence and further clinical improvement. This chapter presents an overview of the patients' esthetic treatment demands, which led to the popularity of this modality of orthodontic therapy, as well as important aspects of the clear aligner method, the orthodontic tooth movement with clear aligners, and the material properties of clear aligners. Clear aligner material efficiency and effectiveness should continue to be studied, as a better understanding of the material properties and treatment outcomes could lead to better sequencing of tooth movement and more efficient treatment.

Keywords: orthodontic aligners, orthodontic treatment, malocclusion, patients' esthetic treatment demands, orthodontic tooth movement, clear aligners material properties

1.1 Introduction

Patients' demands for esthetic orthodontic treatments have grown to include esthetic appliances, such as ceramic brackets, lingual orthodontics, and clear aligner therapy.[1,2,3] If patients' orthodontic treatment motivations are esthetically driven, they may prefer a more attractive appliance as well. More Invisalign patients reported seeking treatment to improve their appearance (85 vs. 67% for fixed appliance patients), whereas more fixed appliance patients reported seeking treatment because their dentist referred them (26 vs. 3% for Invisalign patients).[4]

Companies including Align Technology (Santa Clara, California, United States), Allesee Orthodontic Appliances (Sturtevant, Wisconsin, United States), and Smile Direct (Nashville, Tennessee, United States) have developed a method of fabricating custom-made clear aligners designed to gradually and sequentially move teeth to their desired positions.[5] The short-term chemical and physical changes, as well as the structural conformation and leaching before and after use, have been previously studied on Invisalign (Align Technology).[6,7,8] Invisalign changed in 2013 the material that was used in making their aligners to SmartTrack aligner material, which continues to be a polyurethane-based material but has been claimed to have increased elasticity and a more precise fit.[9] To date, no studies have investigated the mechanical properties of the clear aligners manufactured by Allesee Orthodontic Appliances, including Simpli5 and Red, White and Blue, or that of Smile Direct. The latter is a relatively recent entry to the market place with no evidence in the scientific literature to verify its claims of efficacy and efficiency in treatment.

Treatment efficacy with clear aligners has been reported to be 41 to 59%, but further investigation in material behavior is needed for improvement.[10–12] The force delivery properties of aligners are influenced by both the direction of displacement and the stiffness of the material used.[13,14] A more recent study has found that the orthodontic force produced by a thermoplastic material is strongly correlated with its hardness and elastic modulus. Therefore, any significant differences in the properties of clear aligners may have an impact on what aligner system the practitioner chooses to use.[15] Material properties may even affect the treatment outcome, as it was found that patients wearing a harder aligner material for a 2-week activation time showed the best results in all measurements of occlusal and alignment improvement, although the difference was not statistically significant.[16]

It is also important to determine if the material's properties change after use, as biofilm modification and oral environmental conditions may have

*This chapter is dedicated to the memory of Dr. Lauren Teske, a colleague, mother, and friend.

effects on the hardness and viscoelasticity of the material.[17] Previous studies have detected changes in the Invisalign material after use, including increased hardness, decreased mechanical properties, abraded cusp tips, integument adsorption, biofilm calcification, microcracks, delamination, and loss of transparency.[6,7,8]

1.2 Esthetic Treatment Demands

Patients' demands for esthetic orthodontic treatment have grown to include any type of esthetic appliances which are minimally visible.[1,2,3] The appearance of orthodontic appliances plays a significant role in patients' decisions to receive orthodontic treatment. A survey found that 33% of young adults would be unwilling to wear visible braces if needed.[18] Another study noted that while traditional metal brackets were found to be esthetically acceptable to only 55% of adults, clear aligners were acceptable to over 90%.[1] Furthermore, they showed no difference in acceptability ratings when considering the appliances for their own treatment or for their children's treatment, and they were willing to pay more for appliances they deemed more esthetic. Clear aligner preference extends to adolescents as well, as surveyed 15- to 17-year-olds rated clear aligners most acceptable and attractive over ceramic, self-ligating, traditional, and shaped brackets.[19]

As more adults are seeking orthodontic treatment, esthetic improvements of appliances may be a major factor in the increase of acceptability of orthodontic treatment in this group of patients. Perceived personal characteristics of adults may be influenced by their dental appearance and orthodontic appliance design: greater perceived intellectual ability was associated with the appearance of no appliance or aligner appliances compared to steel or ceramic appliances.[3] This could likely influence the patient's orthodontic appliance choice. If their treatment motivation is esthetically driven, they may prefer a more esthetic appliance as well.

1.3 Clear Aligner Therapy

Companies including Align Technology and Allesee Orthodontic Appliances have developed a method of fabricating custom-made clear aligners designed to gradually and sequentially move teeth to their desired positions (▶Fig. 1.1).[5] The short-term chemical and physical changes, as well as the structural conformation and leaching before and after use have been previously studied on Invisalign (Align Technology).[6,7] However, Invisalign has recently changed the material that was used in making the aligners to SmartTrack aligner material, which continues to be a polyurethane-based material.[9] Align Technology states that the SmartTrack material delivers a lower initial insertion force for improved patient comfort, while maintaining more constant force over the 2-week wear. Additionally, it is claimed to have higher elasticity and a more precise fit. This is beneficial in that it improves tracking and control of tooth movements.[20] No studies to date have investigated the mechanical properties of the clear aligners manufactured by Allesee Orthodontic Appliances, including Simpli5 and Red, White and Blue. Both systems use the company's highly esthetic proprietary material and are designed to treat minor to intermediate anterior misalignment, only differing in the number of aligners the patient has to wear to correct the misalignment.[21]

The aligner manufacturing process differs for the two companies. Align Technology uses stereolithography technology to create plastic resin models from photoactivated polymer.[5] The patient's polyvinyl siloxane (PVS) impressions are scanned and converted into three-dimensional electronic

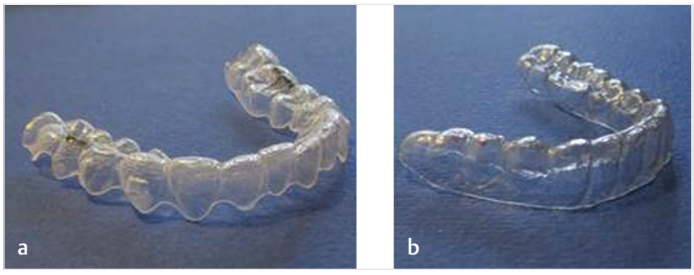

Fig. 1.1 **(a)** Unused Invisalign and **(b)** Simpli5 mandibular aligners.

models, where the teeth are electronically separated and moved by a technician. Alternatively, the models can be fabricated directly from the patient's intraoral scan.[22] Each stage of treatment is converted into a physical model with a stereolithography apparatus, and an automated aligner system heats, forms, and laser-marks sheet plastic over each model.[5] Ridges from the model formed by stereolithography can be seen in the finished aligner material, and the tray is scalloped along the gingival margin (▶Fig. 1.2). Conversely, Allesee Orthodontic Appliances fabricates their aligners from stone models where the individual teeth are manually sectioned by lab technicians and repositioned with wax.[23,24] The finished product is highly transparent with a straight-line finish instead of scalloping the gingival margins (▶Fig. 1.2). Each system produces clear aligners from the models, each corresponding to a 2- to 3-week interval of treatment. Progressive alignment of 0.25 to 0.5 mm is designed into each aligner.[25] Aligner systems including ClearSmile and Raintree Essix allow more displacement in each aligner (0.5–1 mm) compared to the Invisalign system (0.25–0.33 mm).[25,26]

Benefits of clear aligner therapy include esthetics, comfort, oral hygiene improvement, and reduced chair time.[27] Adult Invisalign patients have reported less pain and fewer negative impacts on their lives than those with fixed appliances.[4,28] Those with fixed appliances took more pain medication during the first week of orthodontic treatment than the Invisalign patients.[4] Adolescents also have positive attitude to aligners. The vast majority did not limit foods, avoid communication, or feel self-conscious while wearing the aligners.[29] After 3 months, 70% had seldom or never experienced discomfort, and 80% had seldom or never used pain relievers. As treatment progressed, the patients reported even less discomfort.[29] In addition to improved comfort, clear aligners also show favorable consequences for periodontal health compared to fixed appliance treatment.[30] After 24 months, teenagers using Invisalign Teen aligners had the plaque index decreased by 15.1% in the maxilla and 16.6% in the mandible.[29]

Orthodontic appliances must be selected on the basis of more than appearance, as the appliances must have desirable functional properties and treatment outcomes. A systematic review in 2005 determined that there was not sufficient evidence to adequately evaluate Invisalign treatment effects, and that high-quality clinical evidence was needed.[31] Since then, there have been numerous studies that have looked at the efficacy and treatment outcomes of Invisalign treatment. Treatment efficacy with clear aligners has recently been reported to range from 41 to 59%.[10,11,12] While the reported treatment efficacy numbers are low, case reports have shown successfully completed moderate to difficult orthodontic malocclusions, including open bite, extraction, and surgical cases.[32,33,34,35,36,37] Furthermore, resolving moderately severe anterior crowding can be successfully accomplished with Invisalign.[38]

Treatment outcomes of Invisalign have been compared to fixed appliances using the objective grading system of the American Board of Orthodontics. Compared to traditional braces, Invisalign lost an average of 13 more points and had a 27% lower passing rate.[39] While the strengths of Invisalign included its ability to close spaces and correct anterior rotations and marginal ridge heights, it was deficient in correcting large anteroposterior discrepancies and occlusal contacts.[39] Evaluation of dental casts of patients treated with Invisalign

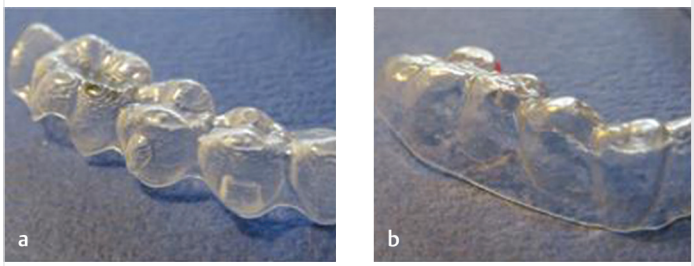

Fig. 1.2 Aligner material. **(a)** Invisalign aligner. Notice the generalized ridges from the stereolithographic manufacturing process, the impression of the attachments on the premolars, and how the aligner is scalloped along the gingival margin. **(b)** Simpli5 aligner. The material appears more translucent in comparison to Invisalign and the edge is trimmed straight across the gingival margins of the teeth.

Fig. 3.1 **(a)** A case with bilateral posterior crossbite. **(b)** Posterior crossbites corrected using a Hyrax expander over a period of 2 months, followed by comprehensive orthodontic treatment using the Invisalign appliance. **(c)** Images showing occlusion after immediate Hyrax expansion.

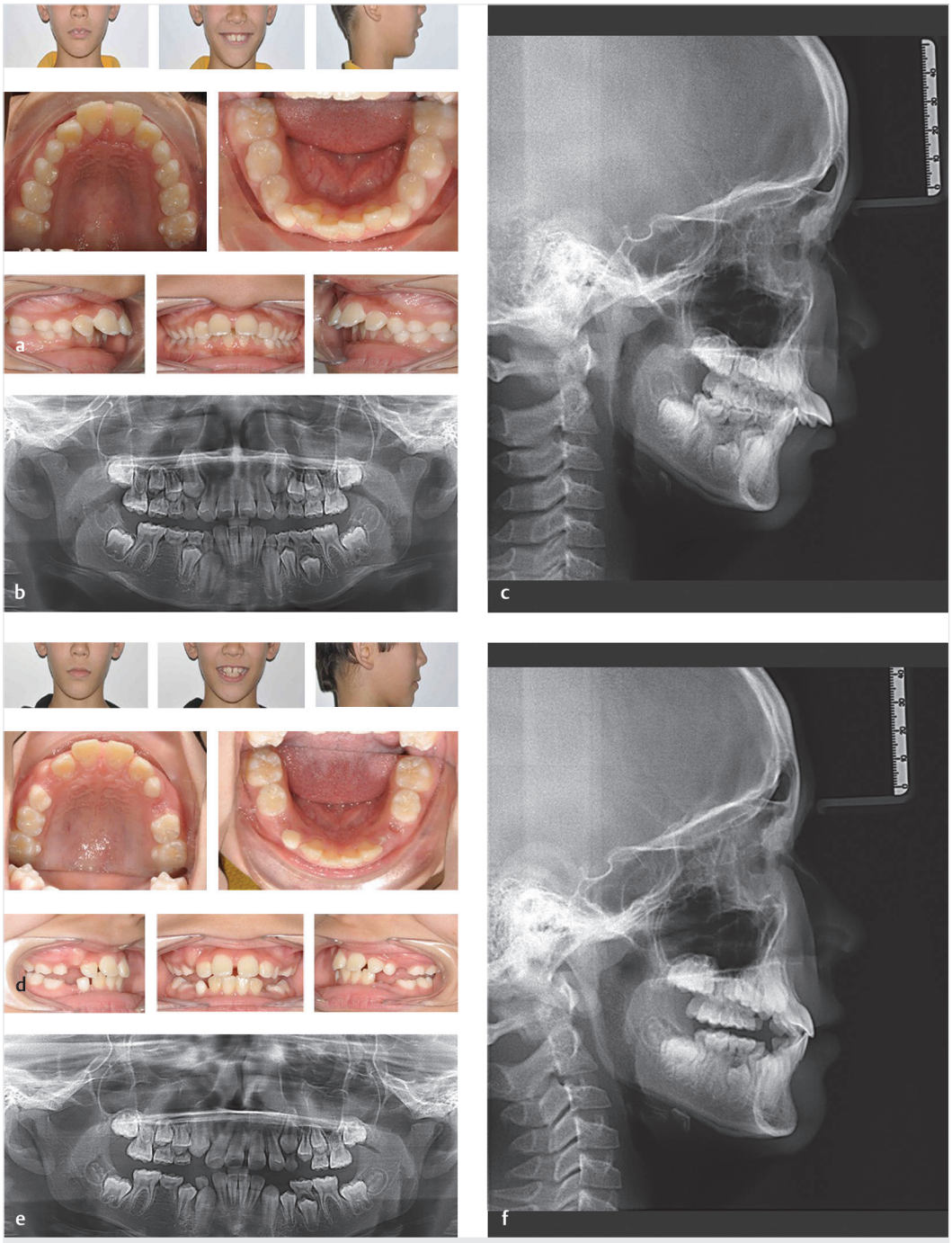

Fig. 3.5 **(a)** Early interceptive treatment of a 10-year 1-month old child with a removable functional appliance. **(b)** Pretreatment panoramic radiograph. **(c)** Pretreatment lateral cephalometric radiograph. **(d)** Interceptive treatment completed in 10 months. **(e)** Post stage I treatment panoramic radiograph. **(f)** Post stage I treatment lateral cephalometric radiograph.

(*Continued*)

Fig. 3.24 (*Continued*) **(c)** Immediately after mandibular advancement. **(d)** Completion photos.

(*Continued*)