

Efficiency, three-dimensional planning and prediction of the orthodontic treatment with the Invisalign® system: a case report

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Abstract

The increasing technology improvement applied to softwares for the diagnosis, treatment and prediction in Orthodontics and Facial Orthopedics, has made possible the creation of virtual three-dimensional casts of the dental arches by the digital scanning of a patient's orthodontic impressions. These precise virtual models can be manipulated with a software, creating successive (sequential) dental movements of an initial stage of the malocclusion (the patient's clinical situation) in order to achieve a desirable final tooth positioning and a normal occlusion. Physical casts of each tooth movement stage can be created by the stereolithographic process, allowing the production of a series of fine, transparent and adjusted appliances (aligners). These successive aligners must be used full time, so that they can reproduce the dental movements programmed in each stage of the virtual planning. The malocclusions, involving light to mild crowding and spacing, as well as more complex cases, have successfully been treated by the Invisalign® system. Based on the diagnosis and determined therapeutic goals, this is an efficient system (material and method) and an alternative for the orthodontic treatment of patients during the full permanent dentition phase. This clinical case report aims at showing the efficiency and accuracy of this system concerning its virtual treatment planning and prediction in comparison to the clinical outcomes (real treatment).

Key-words: Orthodontic Treatment. Invisalign System. Three-dimensional Image (3D).

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INTRODUCTION

The dental movement concept through sequential stages individually planned by a “set-up” in casts, and the use of elastomeric appliances have initially been suggested by Kesling¹ and later on by Ponitz², and others, such as McNamara, Kramer, Juenker³, Sheridan, Ledoux, McMin⁴, Rinchuse and Rinchuse⁵, and Lindauer and Schoff⁶. The limitation of these methods described until then was the small magnitude of the changes achieved, associated to the technical difficulties, among them, to manually subdivide in stages a movement desired in several small movements (unique or progressive “set-up”).

In 1998 in the USA, the Align Technology developed the Invisalign system for the orthodontic movement. This treatment method was the first one to be exclusively based on a three-dimensional digital technology (3D). A series of algorithm stages is produced to move the teeth into 0.15 to 0.25mm successive precise movements, using computer programs that manipulate the 3D (virtual) images of the individual malocclusions. For each stages stereolithographic casts are produced, over which 0.7mm thick transparent appliances (aligners) are created, fully adapted to the dental crowns. These aligners, properly numerated according to the treatment stages, must be sequentially used by the patient for an average of two weeks (14 days) each. These transparent and removable aligners juxtaposition to the dental crowns determines a singular esthetic condition with a favorable buccal hygiene concerning the malocclusions correction.

A first clinical study with the Invisalign system, performed by Boyd, Miller and Vlas-kalic⁷ in the Pacific University, San Francisco, California (USA), reported the success of the treatment outcomes in malocclusions involving light to mild crowding and spacing from 3 to 6mm. In a recent study, Boyd and Vlas-kalic⁸ showed and discussed the clinical findings and limitations of the Invisalign system concerning the treatment of complex malocclusions, as cases with deep-bites, premolar

teeth and lower incisor extraction, molar distalization, dental extrusions, open-bites, and patients showing periodontal problems. These authors discussed the esthetic advantages, comfort, hygiene and removable condition of the appliances, as well as the clinical limitations of this method, described as: the selection of cases (diagnosis), financial cost, experience with computerized planning, difficulty in obtaining wide movements, mainly extrusion and rotation, and also the cases involving impacted teeth or during the mixed dentition. The association of attachments as those bonded with composite to the enamel surface, partial cuttings in the aligners, bonding of buttons to the tooth or to the aligners, and the application of intra- and inter-maxillary elastics were suggested as efficient auxiliary elements for controlling the undesirable effects and reducing the system limitations.

Aim

This clinical case report aims at comparing the virtual treatment determined by the orthodontist's prescription and the three-dimensional images obtained by the Invisalign System ClinCheck1.7 software, to the real treatment, i.e., to the clinical outcomes. The purpose was also to evaluate the clinical implications of the system for both patient and professional, as well as to discuss the efficiency, advantages and limitations of the Invisalign system as an alternative method concerning the orthodontic treatment.

The Clinical Case Presentation

Diagnosis

The diagnosis performed based on the anamnesis, clinical and radiographic examination, evaluation of the panoramic radiograph, lateral and frontal cephalometries, and model analysis, determined the following clinical values for the patient's signs and symptoms: male patient, leukoderma, 15-year-11-month-old at the beginning of treatment, having all permanent teeth fully erupted and in occlusion, except the third lower molars that were not present and the upper ones that were in formation. The patient showed

a harmonic and mild retroverted face (dolychofacial) and a lightly convex profile. The patient had a skeletal Class I (orthognatic), Class I dental relation in the molar region and Class II canines relation (1/4cusp) with light anterior constriction of both arches. Upper anterior dental protrusion, overbite (+4.5mm), overjet (+4mm), mild anterior maxillary spacing and unleveling, premolars and canines were mesial rotated (markedly tooth 1.3), light lower anterior crowding, extrusion of right upper central incisor (tooth 1.1) and lower anterior teeth, and a slight mandibular midline deviation (1mm to the right). The functional pattern was balanced without therapeutic needs. (Fig. 1 A-H).

Orthodontic therapeutic aims

The main treatment goals were: a mild anterior expansion of the upper and lower dental arches, alignment and leveling of the mandibular and maxillary teeth, including the retraction of the upper anterior teeth and selective intrusion of tooth 1.1 and lower anterior teeth with axial correction (derotation) of the premolars and canines, ending in a Class I occlusal relation of the canines, with improvement of the overjet and overbite.

Therapeutic materials and methods selection

After making the orthodontic aims clear to both the patient and parents, the alternatives of materials and methods compatible to the treatment goals were discussed. In this clinical case, the treatment efficient possibilities were: buccal fixed orthodontics, lingual fixed orthodontics or Invisalign system. Accordingly, considering the system advantages, the compatibility with the treatment aims and the patient's (post-adolescent) refusal to use fixed appliances, the treatment was decided to be carried out with the Invisalign system.

Orthodontic planning and treatment conduction with the Invisalign system

Following the protocols to send the clinical case to Align Technology (Santa Clara, California, USA) the impressions and bite registration were made in PVS (polyvinylsiloxane)

that together with our orthodontic planning prescription, photographic and radiographic documentation determined the "virtual treatment" performance by the scanning and manipulations with the ClinCheck 1.7 (3D) three-dimensional software.

After processing (transferring) the treatment planning to the three-dimensional images of both dental arches, we received the "virtual treatment" according to our prescribed planning. This software and images were accessed and saved via internet. It is up to the orthodontist, together or not with the patient, to accept or still modify the three-dimensional planning initially prescribed according to individual professional criteria and responsibility. In this phase, the final result of the virtual treatment is determined as well as the quantity of stages (aligners) necessary for the orthodontic corrections and, consequently, the estimated total treatment time (Fig. 2 A, B; 3 A, B; 4 A, B). We should consider that, the bigger the amount of teeth and extension of movement to be performed are, the bigger the quantity of successive aligners and the estimated total treatment time will be.

In this clinical case, 13 upper stages (aligners) and 14 lower stages were established for this planned orthodontic correction. We opted also for the placement of vertical attachments in all canines, upper first premolars and lower premolars to obtain a better control of rotation, inclination and intrusion/extrusion by additional retention and mechanical adaptation determined by these elements. We requested an overcorrection of 2 stages for the teeth 1.3 and 4.2, due to their more unfavorable initial positioning. Therefore, we could predict an estimated total active treatment time of about 7 months with the aligners (14 aligners for 2 weeks each). This prediction is applied since the placement of the first aligner with the patient's total compliance (full-time use of the aligners, removal only during the meals) and assiduous returns to the orthodontist when all stages through the aligners adaptation are carefully checked and then changed sequentially.

After accepting the virtual planning and treatment, the phase of manufacturing the determined aligners (stages) sequence began. At the end of this process, we received (via express mail) this aligners sequence properly numbered and packed, as well as the templates for the attachments manufacturing predicted for this clinical case.

The orthodontic treatment performance and outcomes with the Invisalign system

The treatment began with bonding the attachment to the enamel of the predicted teeth with light-cured composite (Transbond LR, 3M), after conventional prophylaxis and etching of the involved surface. The templates determined, in negative (depressions), the attach-

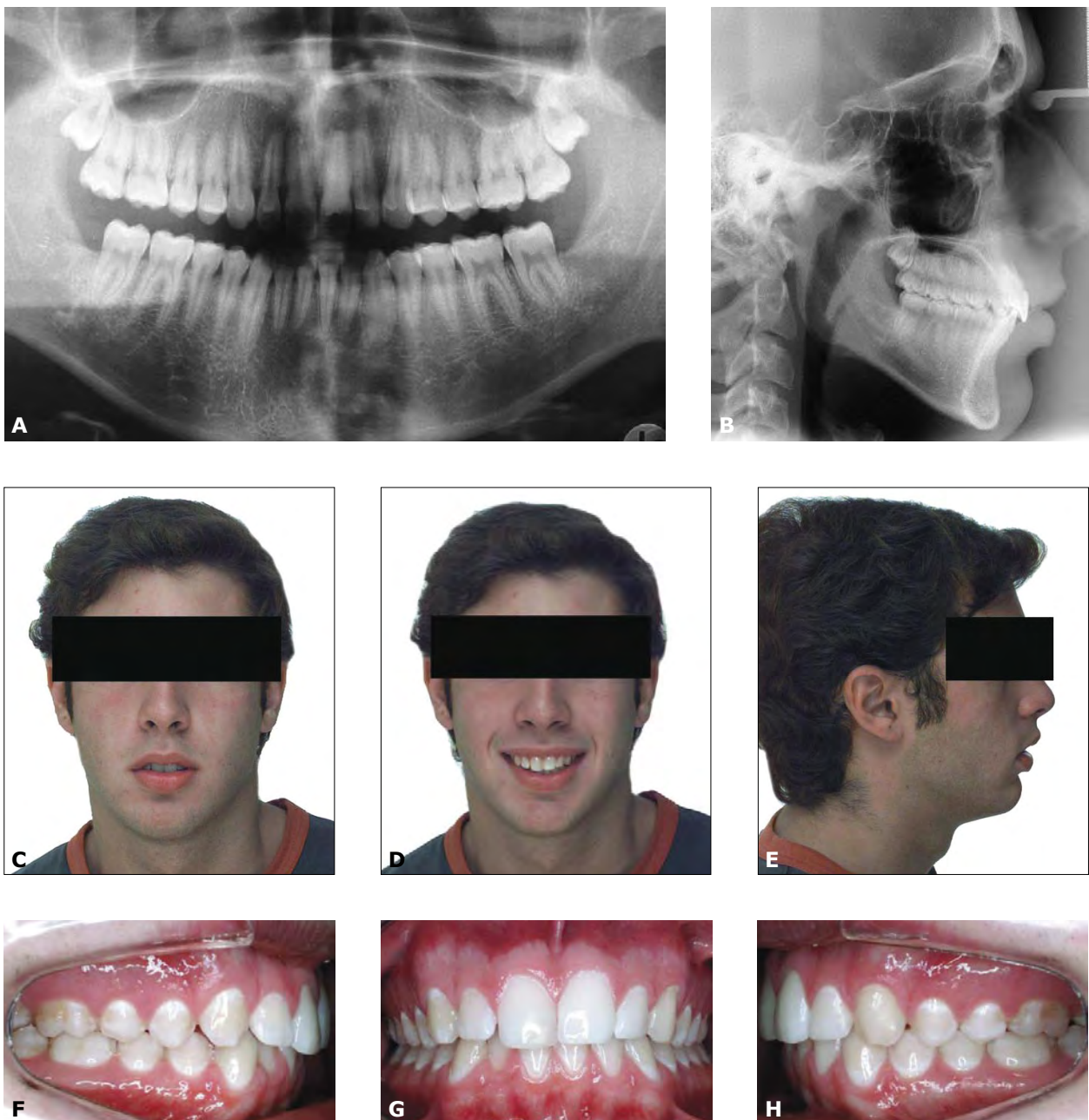


FIGURE 1 - The patient's initial findings. (A) Initial panoramic radiograph. (B) Initial lateral ceph. (C) Initial frontal facial photograph. (D) Initial frontal facial photograph with smile. (E) Initial facial photograph of the patient's profile. (F) Initial intra-oral photograph - right side. (G) Initial intra-oral photograph - frontal. (H) Initial intra-oral photograph - left side.

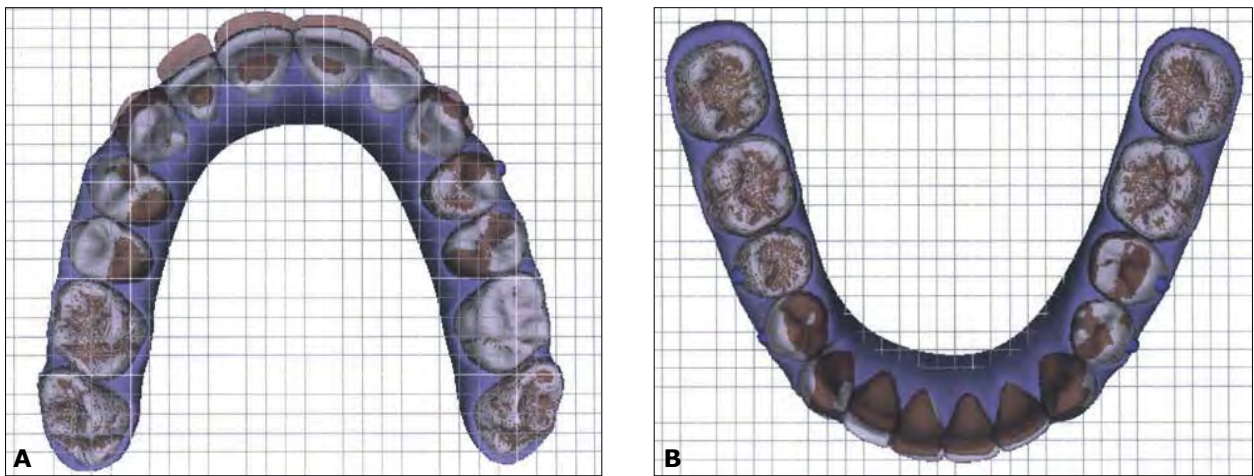


FIGURE 2 - Superimposed virtual three-dimensional images of the initial stage (shadow in brown) and the final stage (in white) in the occlusal norm, with the grid in a 2mm scale. (A) Upper arch. (B) Lower arch.

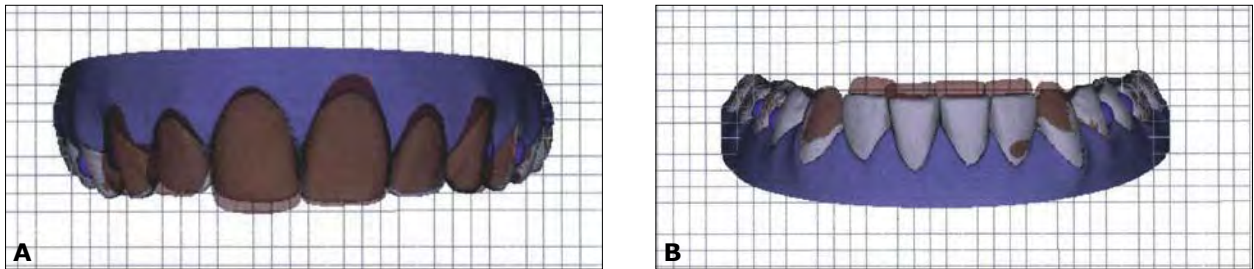


FIGURE 3 - Superimposed virtual three-dimensional images of the initial stage (shadow in brown) and the final stage (in white) in the frontal norm, with the grid in a 2mm scale. (A) Upper arch. (B) Lower arch.

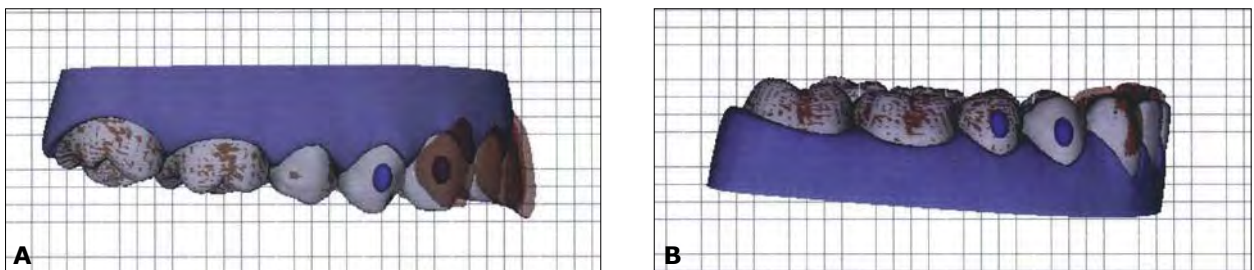


FIGURE 4 - Superimposed virtual three-dimensional images of the initial stage (shadow in brown) and the final stage (in white) in the lateral norm, with the grid in a 2mm scale. (A) Upper arch. (B) Lower arch.

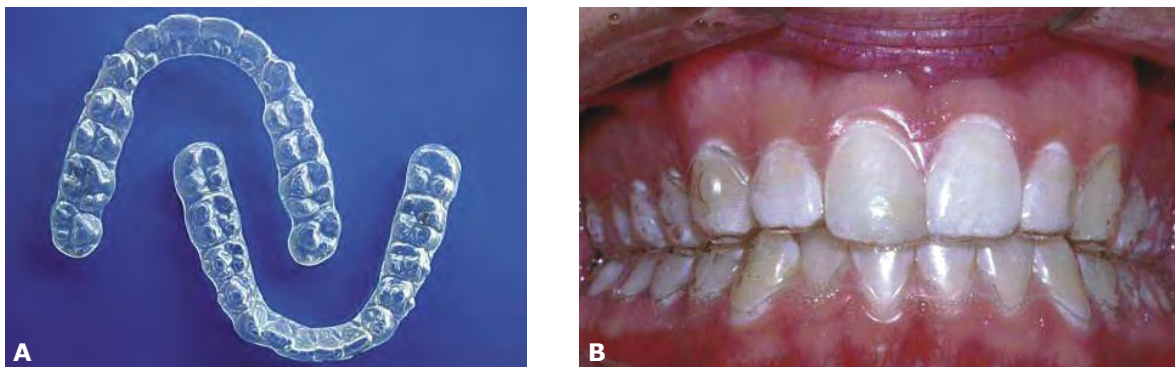


FIGURE 5 - (A) Upper and lower aligners. (B) The patient's frontal intra-oral photograph with the aligners.

ments dimensions to be filled with composite material, adapted to the teeth surfaces and then light-cured. Afterwards, the first aligners of the series (1st of 13 upper and 1st of 14 lower ones) were carefully inserted, controlling adaptation of all the teeth to the aligners (Fig. 5 A, B). Based on this condition, an interval of two weeks (14 days) was determined for a new adaptation control, comparison to the virtual stage (ClinCheck) and consequent change of the aligners to the next ones of the sequence. In this clinical case, considering the patient's good compliance, the aligner changes in all stages were made according to the pre-determined period of 2 weeks. Exception occurred with the 7th stage aligners, when the patient, concerning his less compliance in using them, was asked to use better the same aligners

for two additional weeks. Coming back after this period and checked the adaptation requirements, this stage was achieved and the aligners changed. According to these method of control, this treatment was followed until the last aligners of the series, achieving the planned and predicted results in the virtual treatment (Fig. 6 A-C; 7 A-C; 8 A-C; 9 A-C). The active total treatment time was 8 months. The patient continued using the final aligners, as an initial retention during the next two months. The treatment evolution including all successive stages and the achieved final clinical result were compared to the virtual treatment predicted in the beginning of this therapy, through the three-dimensional images of the Invisalign system ClinCheck1.7 software (Fig. 10 A-E; 11 A-E; 12 A-E and 13 A-E).

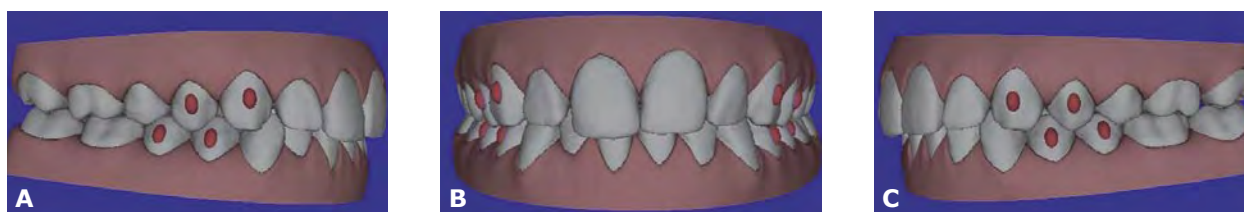


FIGURE 6 - Virtual three-dimensional images of the initial stage: (A) Right side. (B) Frontal. (C) Left side.



FIGURE 7 - The patient's intra-oral photograph at the beginning of treatment: (A) Right side. (B) Frontal. (C) Left side.



FIGURE 8 - Virtual three-dimensional images of the final stage: (A) Right side. (B) Frontal. (C) Left side.



FIGURE 9 - The patient's intra-oral photograph at the end of treatment: (A) Right side. (B) Frontal. (C) Left side.

DISCUSSION

Discussion of the clinical case findings

A full achievement of the expected treatment goals (Fig. 14 A-H) was observed. The orthodontic planning and treatment by these materials and methods together with the patient's good compliance, determined teeth movements that fulfilled the following therapeutic aims: a mild anterior expansion in the upper and lower arches, appropriate alignment and leveling of the dental arches with effective retraction of the maxillary anterior teeth, a selective intrusion of tooth 1.1 and lower anterior teeth, and correction of premolars and canines rotations. Therefore, a Class I relation of the canines was achieved with more appropriate over-jet and over-bite and an enhanced esthetics of the smile. These findings correspond to those obtained by Boyd, Miller and Vlaskalic⁷, who first revealed efficiency of this method as an orthodontic treatment alternative for clinical cases with mild to moderate malocclusions.

Discussion of the orthodontic treatment with the Invisalign system

One first aspect of great visual impact regarding the professional-patient or professional-professional communication is due to the use and manipulation of accurate three-dimensional images of the patient's dental arches by the Invisalign system with the ClinCheck1.7 software. This tool allows a faithful visualization and prediction of the treatment in three dimensions (3D) prescribed by the orthodontist. From the interactive point of view, it also allows to change some initially prescribed

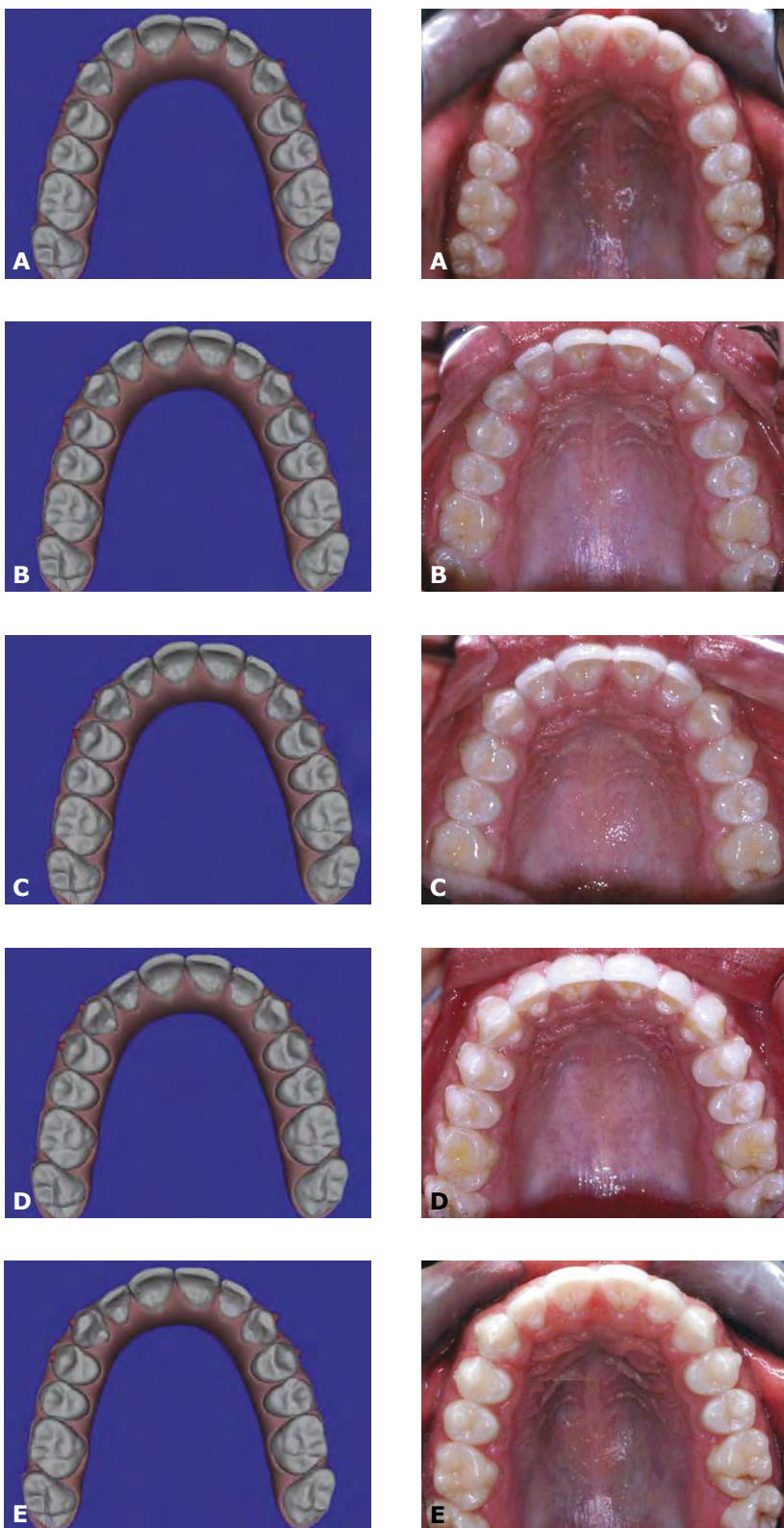


FIGURE 10 - Three-dimensional images of the virtual treatment progression in maxillary occlusal norm. (A) Stage one (initial). (B) Stage five. (C) Stage nine. (D) Stage eleven. (E) Stage thirteen (final).

FIGURE 11 - Intra-oral photograph of the real treatment progression in maxillary occlusal norm corresponding to: (A) Stage one (initial). Stage five. (C) Stage nine. (D) Stage eleven. (E) Stage thirteen (final).

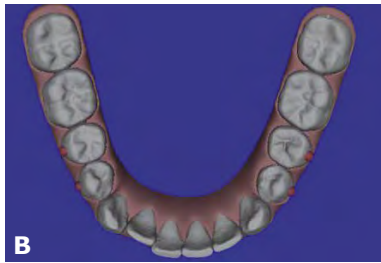
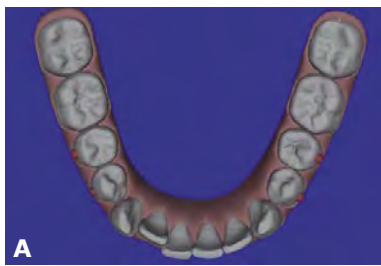


FIGURE 12 - Three-dimensional images of the virtual treatment progression in mandibular occlusal norm: (A) stage one (initial). (B) Stage five. (C) Stage nine. (D) Stage eleven. (E) Stage fourteen (final).

FIGURE 13 - Intra-oral photograph of the real treatment progression in mandibular occlusal norm corresponding to: (A) Stage one (initial). (B) Stage five. (C) Stage nine. (D) Stage eleven. (E) Stage fourteen (final).

movement, modifying the initial planning, progression and treatment outcomes. For the clinician, this means to visually predict the sequence, final result and estimated time of a suggested therapy before it was initiated. This way, it serves as a “self-evaluation” and a reference for possible corrections of the orthodontic planning. It is also important to emphasize that both the selection as the prescription and acceptance of a clinical case planning using the Invisalign system are responsibilities of the orthodontist. Furthermore, this reinforces the need of specific knowledge on diagnosis and compatibilities of the treatment goals with the selected therapy.

Accuracy and stability of the initial impressions and bite registrations in PVS should be carefully evaluated before the application of this system, since it will determine the starting-point of the whole virtual treatment and, afterwards, the clinical consequences. This initial condition must be kept without changes concerning the teeth positioning until the placement and adaptation of the first aligner. This requires professional’s attention, concerning specially the time needed for the ClinCheck performance, its approval or changing, and, finally, the manufacturing and delivering of the aligners. The estimated time for this whole process ranges from 30 to 45 days.

Regarding the treatment clinical application of the Invisalign system, we also emphasize the esthetic appearance, comfort and hygiene, due to the characteristics of the removable aligners, as one of the major advantages of this method to the patient, according to Boyd and Vlaskalic^{7,8}. The patient

reported a full adaptation concerning the speech (phonation) already during the first week using the aligners. He described a supportable degree of sensibility (“pressure on the teeth”) during the first 24 and 48 hours of a new aligner placement (after change), what clinically corresponds to the sequential “activations” offered by a correction

with progressive stages (0.15 to 0.25mm movement for each aligner). The patient also reported that the aligner esthetic condition is so favorable that it passes unnoticed inside the social context. Besides these advantages, the practicability of use and the clinical conduction of this method should be reinforced, considering the reduced chair time,

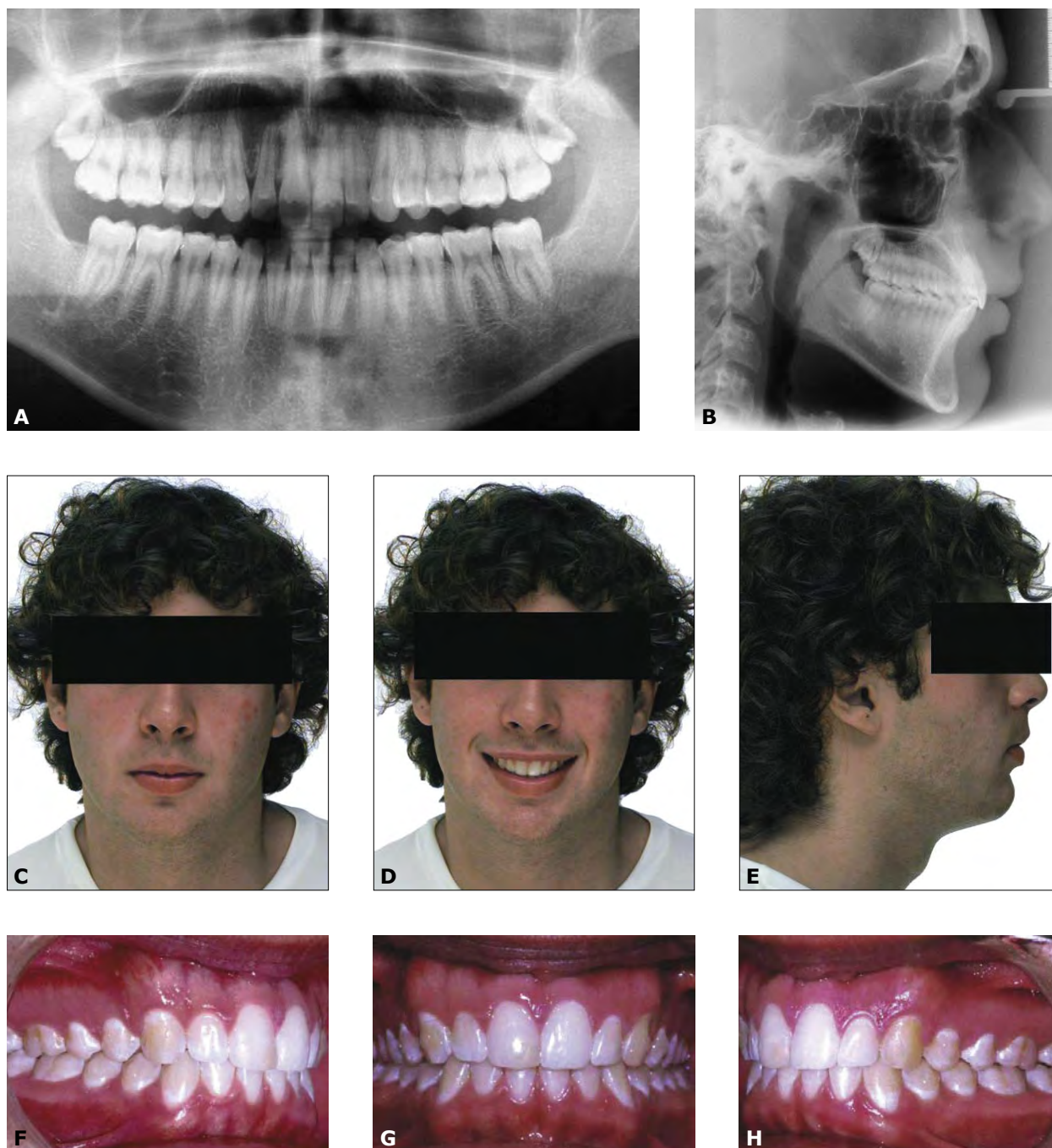


FIGURE 14 - The patient's final findings. (A) Final panoramic radiograph. (B) Final lateral ceph. (C) Final frontal facial photograph. (D) Final frontal facial photograph with smile. (E) Final facial photograph of the patient's profile. (F) Final intra-oral photograph - right side. (G) Final intra-oral photograph - frontal. (H) Final intra-oral photograph - left side.

the predictability and a minor number of inter-currences.

Both the assiduousness to these clinical returns (visits) and the compliance concerning the use and care of the aligners are fundamental in this treatment approach. The professional should instruct, motivate and make the patients conscious so that they can achieve the expected corrections. A higher patient's expectation was also observed, since it is an "invisible" "step by step" alternative therapy and totally different from other conventional well-known ones.

All the advantages and/or disadvantages, together with the efficiency of an alternative method for the orthodontic treatment, are based on an accurate and detailed diagnosis and its consequent therapeutic planning. It is the professional task to know and determine the compatibility of the treatment goals to the proprieties, effects and limitations of the materials and methods to be used.

REFERENCES

1. KESLING, H. D. The philosophy of the tooth positioning appliance. **Am J Orthod**, St. Louis, v. 31, p. 297-304, 1945.
2. PONITZ, R. J. Invisible retainers. **Am J Orthod**, St. Louis, v. 59, p. 266-272, 1971.
3. MCNAMARA, J. A.; KRAMER, K. L.; JUENKER, J. P. Invisible retainers. **J Clin Orthod**, Boulder, v. 19, p. 570-578, 1985.
4. SHERIDAN, J. J.; LEDOUX, W.; McMINN, R. Essix retainers: Fabrication and supervision for permanent retention. **J Clin Orthod**, Boulder, v. 27, p. 37-45, 1993.
5. RINCHUSE, D. J.; RINCHUSE, D. J. Active tooth movement with essix based appliances. **J Clin Orthod** Boulder, v. 31, p. 109-112, 1997.
6. LINDAUER, S. J.; SCHOFF, R. C. Comparison of Essix and Hawley retainers. **J Clin Orthod**, Boulder, v. 32, p. 95-97, 1998.
7. BOYD, R. L.; MILLER, R. J.; VLASKALIC, V. The Invisalign system in adult orthodontics: mild crowding and space closure. **J Clin Orthod**, Boulder, v. 34, p. 203-213, 2000.
8. BOYD, R. L.; VLASKALIC, V. Three-dimensional diagnosis and orthodontic treatment of complex malocclusions with the Invisalign appliance. **Sem Orthod**, Orlando, v. 7, p. 274-293, 2001.

CONCLUSIONS

Considering the treatment goals and outcomes in this clinical case with the Invisalign system, we can conclude that:

1) The comparison between the virtual treatment and the real treatment was highly satisfactory.

2) The planning and treatment with these materials and methods showed a trustful prediction, considering the achievement of the clinical findings compatible in quality, quantity and time to the expected three-dimensional planning.

3) The orthodontic treatment conduction emphasizes the favorable properties from the esthetic, functional and handling point of view, for both professional and patient.

The need of a precise evaluation of the indication and the patient's compliance to this therapeutic approach are fundamental for obtaining the desirable results.

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