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Digital Planning Technique for Surgical Guides for Prosthetic Implants before Orthodontic Treatment

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Featured Application: The authors present a comprehensive digital workflow for the planning of complex orthodontic treatments with implant placement before orthodontic treatment. It suggests a modern way to treat adult patients with tooth loss and occlusion problems in a less time-consuming but medically advanced way.

Abstract: Background: The use of digitalization allows clinicians to plan the position of dental implants in orthodontic patients treated with aligners in the beginning of their orthodontic treatment, instead of waiting until the end of orthodontic treatment, integrating implant restorations with orthodontic biomechanics. Aim: The aim of this case report is to describe a digital workflow for aligner treatment supported by implants, in which implants are placed at the beginning of the treatment and support the orthodontic treatment. Materials and Methods: Digital planning for orthodontic treatment with clear aligners and the preparation of surgical guides for implant surgery before orthodontic treatment are used to solve two multidisciplinary cases. Cone-beam computed tomography (CBCT) and virtual dental impressions are used for the virtual planning. Successively, a surgical guide for implant placement and aligners are used in the treatment plan. Results: The digital orthodontic setup with the integration of the root position allows the clinician to plan the position of dental implants on the final occlusion. The placement of the implant before the start of the orthodontic treatment allows the implants to be used as skeletal anchorage, thereby helping the orthodontic biomechanics. Conclusions: This study describes how to perform a digital workflow with orthodontic virtual planning and the design of surgical guides for implant placement. This technique is potentially promising for complex orthodontic cases.

Keywords: aligners; implants; surgical guide; orthodontics

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1. Introduction

In recent years, increasing numbers of adult patients have sought orthodontic treatment and expressed a desire for esthetic and comfortable alternatives to conventional fixed appliances [1]. Using digital models derived from polyvinylsiloxane impressions or oral scanning allows for computer-simulated treatment planning, which includes setting the treatment goal and designing the staging and auxiliary features [2,3].

However, many patients present some peculiarities, as they are often affected by periodontal disease and frequent tooth loss [4]. In the 21st century, the use of digitalization allows clinicians to place dental implants in orthodontic patients treated with aligners at the beginning of their orthodontic treatment, instead of waiting until the end of orthodontic

treatment, as it was done before. The transferal of the virtually planned implant into the patient's mouth can be performed using a surgical guide, which can be either constructed on a cast (the conventional manual method) or created virtually by means of computer software [5].

Here, the authors present a digital workflow for aligner treatment supported by implants, and report two cases in which dental implants were placed at the beginning of orthodontic treatment using surgical guides made according to the computer-simulated orthodontic treatment plans.

2. Materials and Methods

Digital Workflow for Aligner Treatment Supported by Implants

First, the patient is asked to undergo a cone-beam computed tomography (CBCT) scan in order to gain information about their alveolar bone measurements and the root positions of their teeth. Then, the patient is scanned using a 3-Shape intraoral scanner (TRIOS 3, 3Shape Trios A/S, Copenhagen, Denmark) to make virtual dental impressions and prepare a setup. A setup is a virtually created visualization of the teeth after orthodontic treatment.

The setup is prepared after receiving the scan, which is then shown to the orthodontist and surgeon in order to evaluate whether the implantation of the teeth in question is possible before starting the orthodontic treatment. The evaluation takes into consideration factors such as tooth width, implant width, and the movements of the surrounding teeth during orthodontic treatment.

The orthodontist and surgeon decide that implants can be placed before orthodontic treatment; therefore, the dental technician makes a pontic in setup. A pontic is a virtually created dental crown of the implanted tooth in the setup which does not change in size or move during the whole orthodontic treatment. A pontic can be created using the shape of the existing tooth, if this tooth is going to be extracted. However, if there is no tooth, a pontic can be prepared using adjacent or contralateral teeth as a reference for its anatomy. Furthermore, a pontic can be created by making a wax up of one tooth, or by using standard tooth shapes adjusted for the patient.

The pontic is then placed in the first and final stages of the orthodontic treatment in setup. A superimposition of the first and final stages is created, and the exact position of the implant is detected. When the orthodontist approves the implant position and the whole setup, the information is given to the surgeon.

Second, the surgeon orders a surgical guide. In situations when implant surgery is planned with orthodontic treatment, a surgical guide assists in placing implants exactly where they need to be after treatment. Moreover, a surgical guide replicates the exact surfaces of the patient's intraoral setting and helps the surgeon to drill implants into the bone with optimal accuracy. When ordering a surgical guide, a surgeon must mark whether the implant surgery will be fully guided, or pilot guided. The difference in the accuracy between a fully guided and pilot-guided implant surgery is 0.2 mm, where fully guided is more accurate [6]. A surgical guide is planned by taking into consideration factors such as the system, diameter and length of the implant. Before printing a surgical guide, approval from the surgeon must be received.

Third, the dental technician prepares the surgical guide using 3-Shape Implant Studio Software (3-Shape Global, Copenhagen, Denmark). The programme automatically generates safe zones by matching the first and final stages of the setup and uses a prepared pontic. Afterwards, the surgical guide is printed with layers 150 microns thick from 3D printing resin of photopolymer fluid material using a RapidShape P40 (Straumann, Munich, Germany) series professional 3D printer with high-volume printing. Before giving the surgical guide to the surgeon, it is made sterile by letting it sit in a bath with Globacid ID solution for 15 min and then placing it in an autoclave for 40 min on the soft programme (a maximum of 2.3 Bar) at 121 °C. The flow and responsibilities of guided implantation prior to planned orthodontic treatment with aligners are shown in Figure 1.

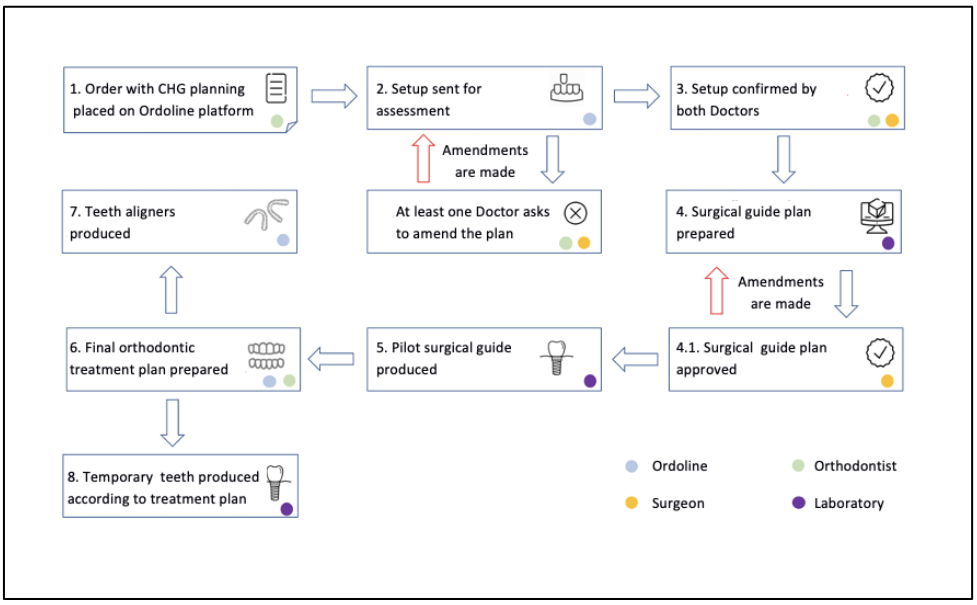


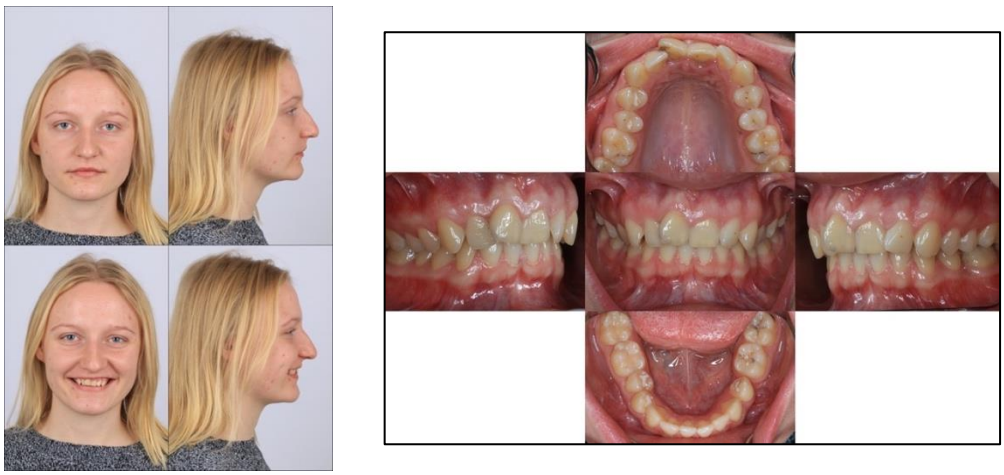
Figure 1. Flow and responsibilities of guided implantation prior to orthodontic treatment.

3. Case Reports

3.1. Case No. 1

A 20-year-old Caucasian female patient searched for orthodontic treatment, complaining about her smile aesthetics. The anamnesis revealed that the patient had experienced trauma to teeth 11 and 21 at an early age.

A clinical examination showed that there was crowding in the upper and lower arches (Figures 2 and 3). The patient presented with Angle Class I on the right side and Angle Class II on the left side. Tooth 35 was missing. The panoramic radiograph revealed that teeth 11 and 21 were treated endodontically (Figure 4). From anamnesis, it was reported that an endodontic treatment was performed due to experienced trauma. Furthermore, tooth 11 was affected by caries. After an examination under a microscope by an endodontist, it was decided that tooth 21 was fractured and should be extracted.



(**a**) (**b**)

Figure 2. Initial pictures of patient in case number 1: (**a**) extraoral pictures, and (**b**) intraoral pictures.

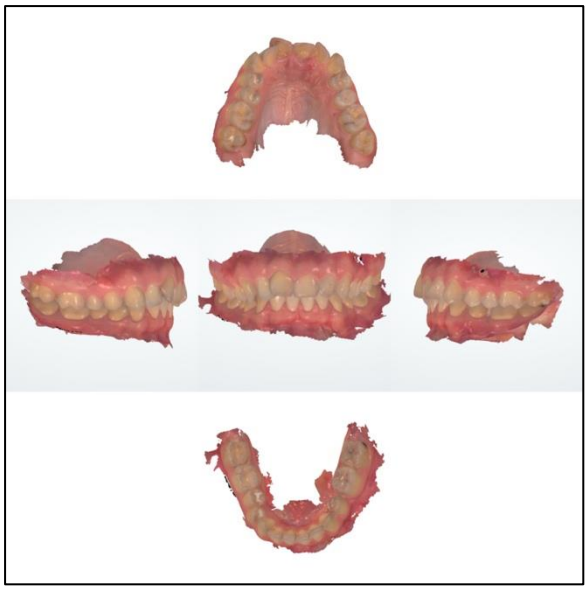


Figure 3. Virtual dental impressions.

Figure 4. Initial panoramic radiograph.

After therapeutic treatment, the patient was referred to both an orthodontist and a surgeon for consultation. Four possible treatment plans were presented:

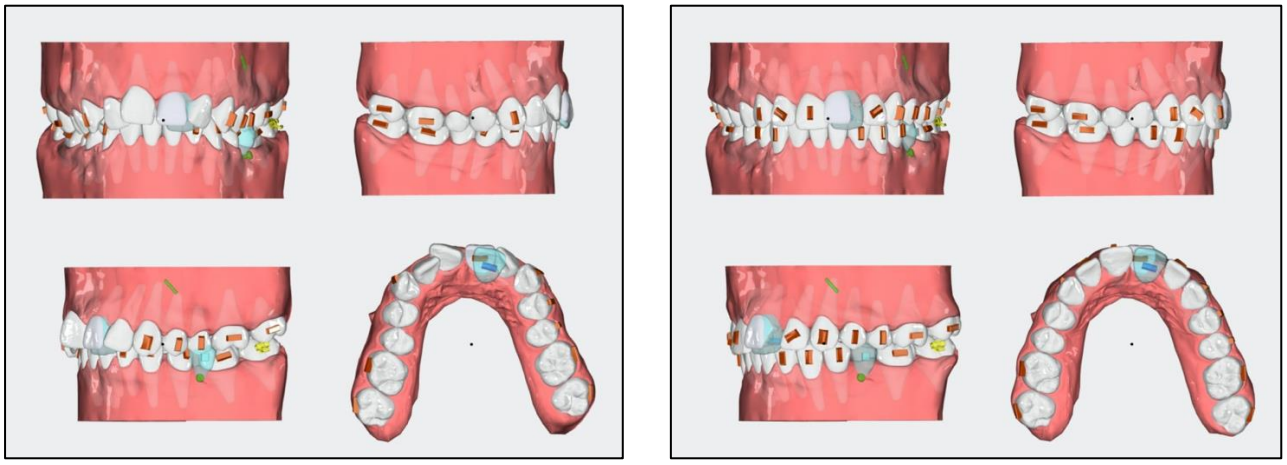
1. The extraction of tooth 21, followed by orthodontic treatment with aligners and guided implant surgery of tooth 21 at the beginning of the orthodontic treatment.
2. The extraction of tooth 21, followed by orthodontic treatment with braces with upper arch distalization and implant surgery of tooth 21 after the orthodontic treatment.
3. The extraction of tooth 21, followed by orthodontic treatment with the extraction of the first or second premolars. This treatment plan was offered but not recommended by the orthodontist.
4. The extraction of tooth 21 with no orthodontic treatment, and implant surgery without a surgical guide.

The advantages and disadvantages of the suggested treatment plans are presented below in Table 1.

Table 1. Advantages and disadvantages of the suggested treatment plans.

Treatment Plan	Advantages	Disadvantages
I	1. 3D setup and accurate planning of final tooth position; 2. Surgical guide for tooth 21 implant planned on teeth in their final position; 3. Distalization of sector 2 to achieve Class I molar relationship using tooth 21 implant; 4. More esthetic treatment; 5. More comfortable for the patient (oral hygiene) [7].	1. The result of orthodontic treatment highly depends on the patient because patient must wear aligners 22 h per day.
II	1. Less expensive; 2. Good occlusion.	1. Implant surgery can be performed only after orthodontic treatment; 2. Less comfortable treatment for the patient.
III	1. Less expensive; 2. Good occlusion.	1. Not recommended by orthodontist; 2. Patient would lose healthy teeth; 3. Due to extraction of premolars, upper front teeth would be distalized and support for upper lip would be lost, therefore upper lip would look smaller.
IV	1. There are no advantages of this treatment method.	1. Angle class would not be corrected; 2. Patient would experience greater and uneven tooth wear; 3. Implant would be placed in the space available now and if the patient decides to perform orthodontic treatment later in life, the possibility for orthodontic treatment would be limited.

After consideration, the patient chose to proceed with plan number I, with the extraction of tooth 21 and implant surgery followed by orthodontic treatment with clear aligners. The workflow of the digital planning for orthodontic treatment supported by implants was as written in Section 2 (Figure 5). It should be stressed that the implant of tooth 21 was placed distally in relation to the center of the alveolus, and this is due to the final position of tooth 21, which must be more distal compared to the initial position of the extracted tooth 21.



(**a**) (**b**)

Figure 5. Digital planning: (**a**) pontics of teeth 21 and 35 at the beginning of the orthodontic treatment; (**b**) pontics of teeth 21 and 35 at the end of the orthodontic treatment.

After receiving the surgical guide, the surgeon planned the procedure. Tooth 21 was extracted and the implant surgery of tooth 21 was immediately performed using a prepared guide (Figures 6 and 7).

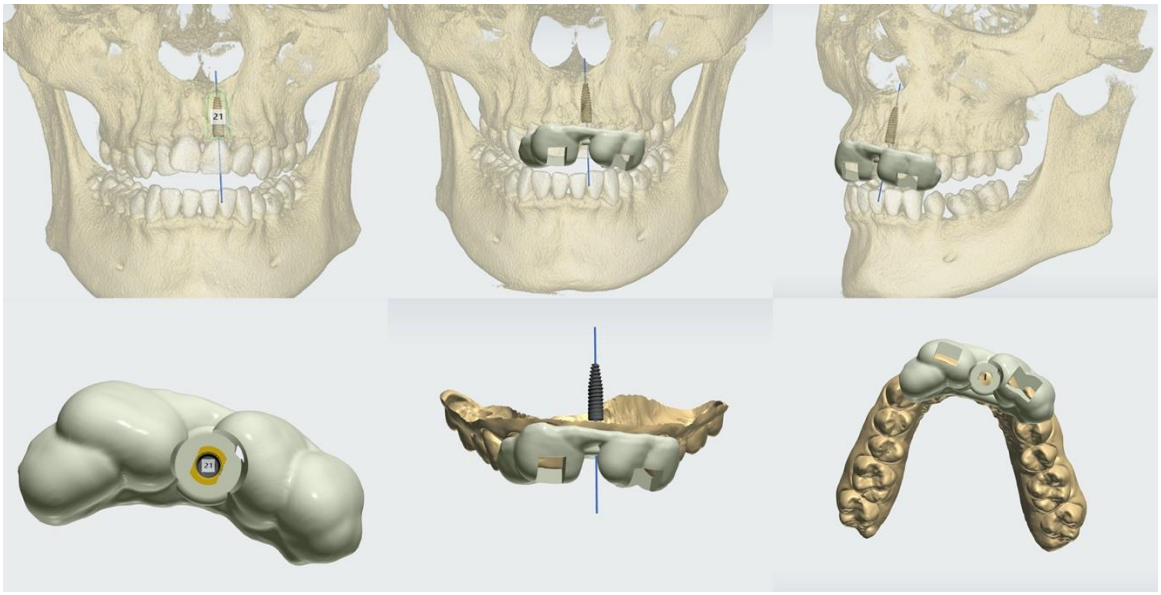


Figure 6. Digital planning of the surgical guide of Case 1.

Figure 7. Using the surgical guide for implant surgery.

Because the procedure was performed in the frontal aesthetic region, a temporary crown of tooth 21 was made using temporary Straumann abutment (Figure 8). It is important to mention that the temporary crown of tooth 21 was excluded from occlusion and all functional moves in order to avoid force on the implant.

After the implant surgery, 3 months were given for the implant to integrate with the bone. After these 3 months the patient was asked to repeat the 3-Shape scanning. The second scan was carried out using a scan body to specify the implant's position, in order to make a clinically proper temporary crown of tooth 21 that would withstand occlusal forces (Figure 9).

Figure 8. Temporary crown after immediate the implant surgery.

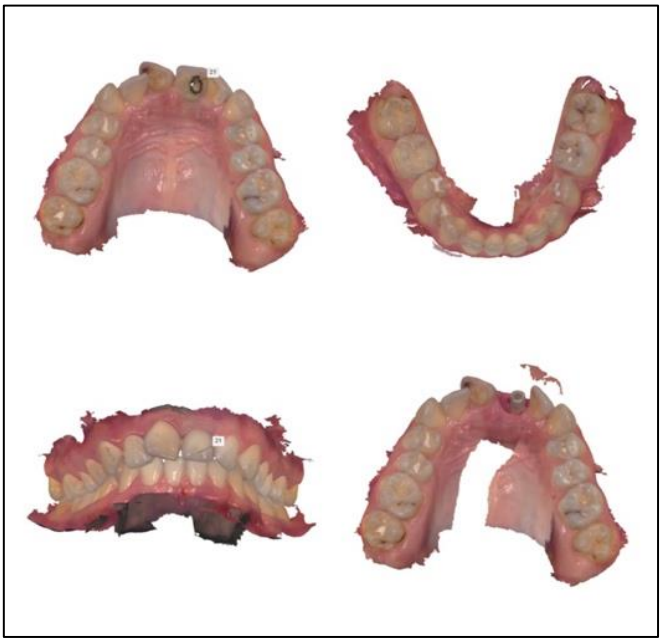


Figure 9. Scan with the scan body.

Moreover, the second scan was performed in order to update the existing 3D plan for orthodontic treatment with aligners. It is important to mention that tooth 35 was missing; however, there was not enough space for an implant for this tooth. Therefore, orthodontic treatment was planned as follows:

- For aligner stages 1 to 16, a mini screw in the area between teeth 34 and 36 was added for the distalization and uprighting of teeth 36 and 37.
- A segment of braces was used to distalize teeth 36 and 37, employing the mini screw as skeletal anchorage. The segment of braces consisted of two metal brackets on teeth 36 and 37, a piece of stainless steel archwire of size 16 × 22, and a heavy-force 9-mm

closed-coil spring. The length of the archwire used was measured by adding 2 mm to the distance between the mini screw and tooth 37, leaving space for the teeth to slide distally.

- The distalization of teeth 16, 17, 26, and 27 was planned with aligners by adding Class II elastics of 6 Oz and a quarter of an inch.
- A horizontal attachment was added onto the temporary crown of tooth 21 for distalization using the implant as skeletal anchorage.
- After stage 16, rescanning should be carried out, and the space for the implant surgery of tooth 35 should be evaluated.

The patient was then at the beginning of orthodontic treatment with aligners (Figure 10).

Figure 10. Intraoral pictures after four of aligners, and with a miniscrew for the distalization of tooth 37.

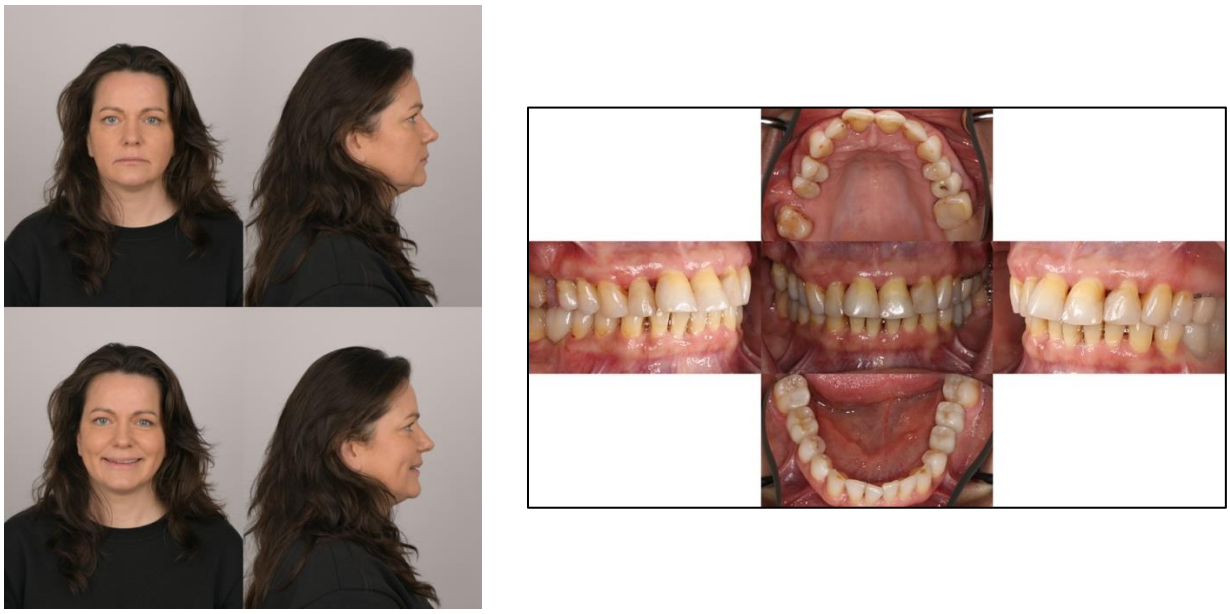
3.2. Case No. 2

A 38-year-old Caucasian female patient sought orthodontic treatment, complaining about teeth spacing.

A clinical examination revealed that the patient did not have tooth 16. The alveolar bone around teeth 14, 15, 17, 24, 25, and 27 had lost more than two thirds of its root length. Moreover, teeth 15, 24, 25, 26, and 27 were treated endodontically. Tooth 26 had root decay. Teeth 36, 35, and 46 were implants (Figures 11–13).

The patient was referred to a prosthodontist, a surgeon, and an orthodontist for consultation. After an evaluation of the clinical situation, it was decided that teeth 15, 24, 25, 26, and 27 had received low-quality endodontic treatment; there was second degree tooth mobility and deep periodontal pockets. It was agreed by the patient that teeth 17, 15, 14, 24, 25, 26, and 27 should be extracted. The patient agreed to undergo orthodontic treatment with clear aligners; therefore, setup was prepared and the implantation of teeth 14, 15, 17, 24, 26, and 27 was performed using surgical guides (Figures 14–16).

The process was the same as described in Section 2. Furthermore, in this case, implants were used as skeletal anchorage to correct the spacing (Figure 16), and the patient was under treatment (Figures 17–19).



(**a**) (**b**)

Figure 11. Initial pictures of the patient in case number 2: (**a**) extraoral pictures; (**b**) intraoral pictures.

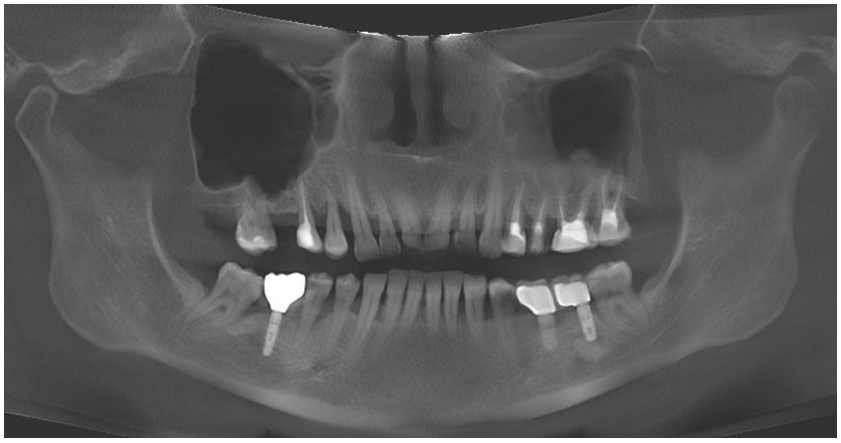
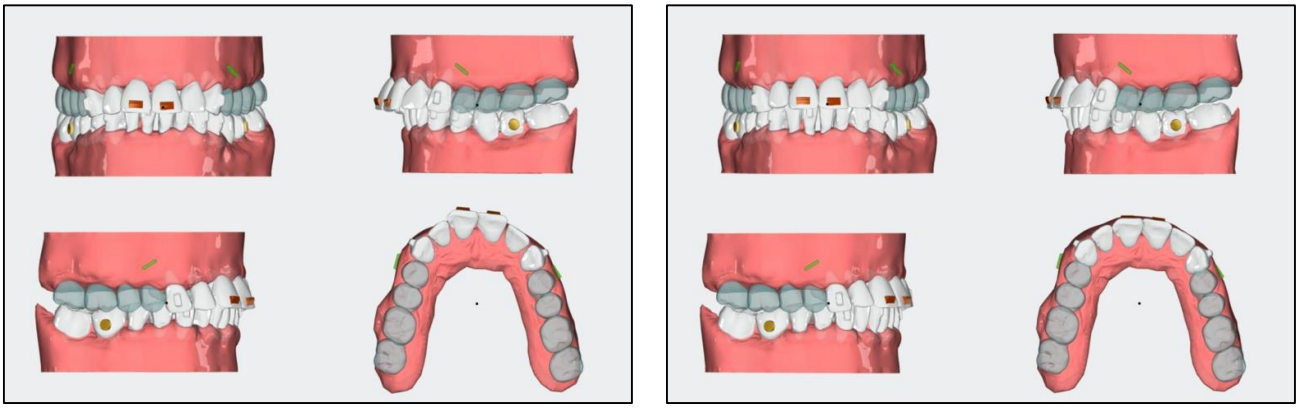


Figure 12. Initial panoramic radiograph of the patient in case number 2.

Figure 13. Scan of the initial situation.



(**a**) (**b**)

Figure 14. Digital planning: (**a**) pontics of teeth 14, 15, 16, 17, 24, 25, 26, and 27 in the beginning of orthodontic treatment; (**b**) pontics of teeth 14, 15, 16, 17, 24, 25, 26, and 27 at the end of orthodontic treatment.

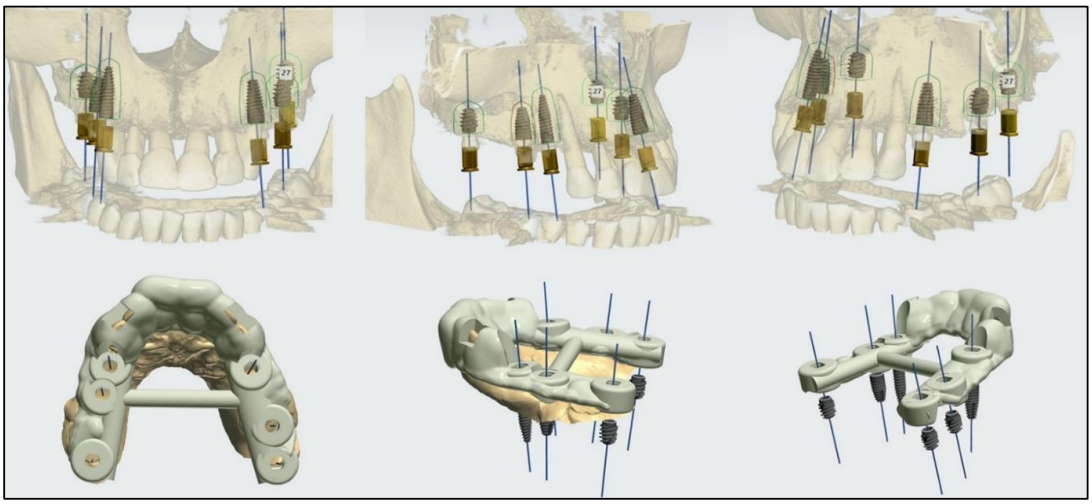
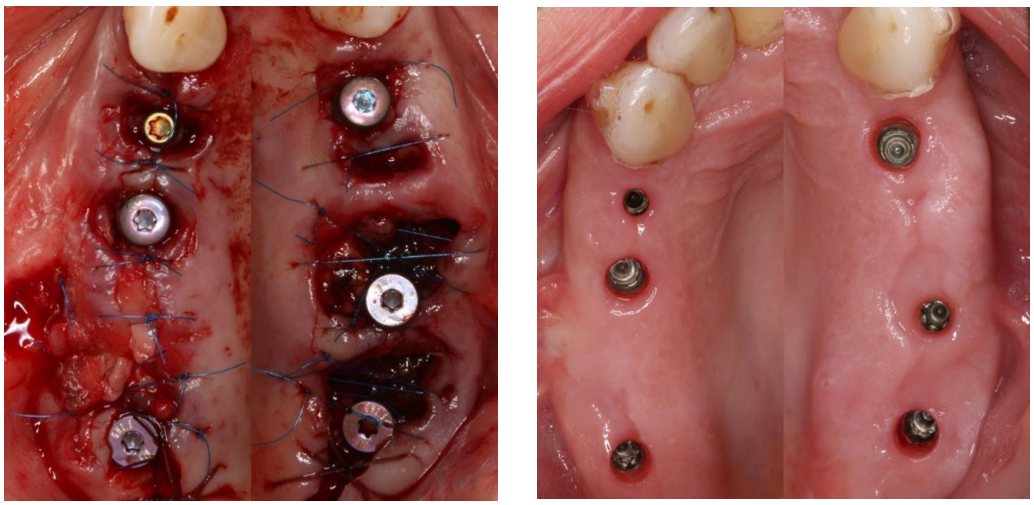


Figure 15. Digital planning of the surgical guide for Case 2.



(**a**) (**b**)

Figure 16. Intraoral pictures of the implants of teeth 14, 15, 17, 24, 26, and 27: (**a**) immediately after surgery; (**b**) 3 months after surgery.

Figure 17. Intraoral pictures with temporary crowns.

Figure 18. Intraoral pictures after the first set of aligners.

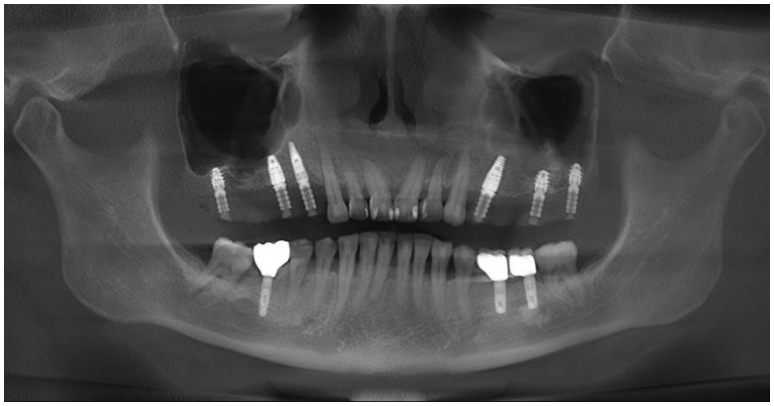


Figure 19. Panoramic radiograph of the patient in case number 2 after space closure.

4. Discussion

Conventional orthodontic methods have been associated with a general compromise in facial appearance, raising a major concern among patients seeking orthodontic treatment [8]. Thus, esthetic materials and techniques have been introduced in clinical practice aiming to overcome these limitations; clear aligners, considering their chemical and physical properties, represent a common solution for adult orthodontic treatment [9,10]. Furthermore, the use of auxiliaries and attachments increase the possibility to treat complex cases in both adults and children [11–14]. Furthermore, the great variability of the available materials increases the possibilities to customize the treatment planning [15–17]. Adult patients present well-defined expectations concerning treatment, requesting a shorter treatment time to resolve their complaints [4]. However, a great deal of adult patients is the presence of tooth loss, which complicates orthodontic treatment and extends treatment time.

In the literature, it is always preferable in aesthetic cases to complete the orthodontic care prior to implant placement [6]. Only in cases of missing posterior teeth can provisional interim implants be placed in order to help the orthodontist establish anchorage [6]. The use of implants for orthodontic anchorage can produce superior preprosthetic tooth movements for partially edentulous patients [18,19]. Interdisciplinary planning can contribute to a successful use of the implants [18]. However, the three-dimensional planning of the implant location site is necessary in order not to compromise orthodontic movement or subsequent prosthetic treatment [18].

There are advantages with the implant treatment modality, e.g., implants replacing premolars for functional aspects and implants replacing incisors for aestethic reasons [20]. Moreover, implants—as a means of enhancing orthodontic anchorage—are gaining increased importance in orthodontic treatment because of the limitations and acceptance problems of conventional intraoral or extraoral anchorage aids or miniscrews, especially in very complex cases [21,22]. Some studies have shown that dental implants placed in the alveolar bone are resistant to orthodontic force [22–25]; therefore, implants help orthodontic biomechanics as skeletal anchorage.

Furthermore, having a digital setup prepared using a CBCT scan is extremely helpful for the surgeon because orthodontic treatments move teeth to find the best position for the implants, and in some cases even help to create bone. This is crucial for the avoidance of surgical complications such as damage and/or perforation into important anatomical structures like the maxillary sinus in the maxilla and the inferior alveolar canal and submandibular fossa in the mandible [26].

Additionally, studies report that using a 3D surgical guide makes precise implant placement possible in partially and completely edentulous patients even with a flapless approach, thereby reducing chairside surgical time, increasing patient comfort post-surgery, and allowing simultaneous implant placement in complex cases [27,28]. Furthermore, implant placement is a technically demanding procedure and, if not performed properly, can lead to various complications such as poor esthetics, damage to anatomically important structures, infections, and implant failure [27]. Therefore, guided implant placement can prevent these complications by the fabrication of surgical guides with the help of 3D printing [27,29].

Despite the advantages, surgeons should not become overly reliant upon 3D-printed guides for surgical safety, and caution should be taken [30,31]. Furthermore, cost is a factor when using 3D-printed templates, but studies have reported it to be justified [27,30]. Nevertheless, it should be noted that even if the space before orthodontic treatment seems sufficient and correct for an implant to be inserted, it might not in the correct position after orthodontic treatment when all of the teeth have moved into their planned places. Therefore, the preparation of the setup is crucial in complex orthodontic cases, including implant surgeries.

In both cases, the patients needed implant surgery, and in both cases, it could be performed at the beginning of orthodontic treatment. However, in case number 1, the implantation of tooth 21 was placed at the beginning of the treatment because it was

an aesthetic area and the patient did not want to be without a first incisor for the total treatment period. In case number 2, the implant placement surgery at the beginning of the orthodontic treatment was extremely helpful for the distalization of the front teeth in the upper arch. Nevertheless, the patient was happy to regain function on their posterior teeth.

5. Conclusions

In conclusion, this study describes how to perform a digital workflow with orthodontic virtual planning and the design of surgical guides for implant placement. This technique is potentially promising for complex orthodontic cases that need dental implants that might be used as skeletal anchorage.

Author Contributions: Conceptualization, R.N. and V.D.; methodology, V.D. and M.S.; software, R.N. and M.S.; validation, R.N., R.K. and V.D.; formal analysis, R.N.; investigation, R.K.; resources, R.K.; data curation, R.N.; writing—original draft preparation, R.N.; writing—review and editing, A.P. and R.R.; visualization, R.N.; supervision, R.R. and V.D.; project administration, R.K.; funding acquisition, R.K. All authors have read and agreed to the published version of the manuscript.

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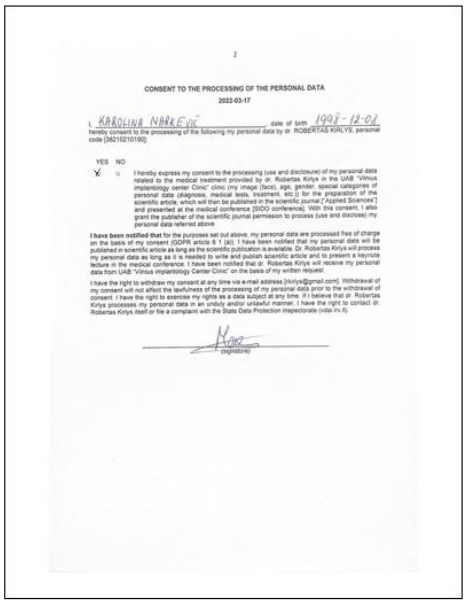
Informed Consent Statement: Informed consent was obtained from all of the subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper. It is presented below.



CONSENT TO THE PROCESSING OF THE PERSONAL DATA

2022-03-17

I, KAROLINA NARKEVIČ, date of birth 1998-12-08, hereby consent to the processing of the following my personal data by dr. ROBERTAS KIRLYS, personal code [38210210190]:

YES NO

X = I hereby express my consent to the processing (use and disclosure) of my personal data related to the medical treatment provided by dr. Robertas Kirlys in the UAB "Vilnius implantology center Clinic" clinic (my image (face), age, gender, special categories of personal data (diagnosis, medical tests, treatment, etc.)) for the preparation of the scientific article, which will then be published in the scientific journal ["Applied Sciences"] and presented at the medical conference [SIDO conference]. With this consent, I also grant the publisher of the scientific journal permission to process (use and disclose) my personal data referred above.

I have been notified that for the purposes set out above, my personal data are processed free of charge on the basis of my consent (GDPR article 6.1 (a)). I have been notified that my personal data will be published in scientific article as long as the scientific publication is available. Dr. Robertas Kirlys will process my personal data as long as it is needed to write and publish scientific article and to present a keynote lecture in the medical conference. I have been notified that dr. Robertas Kirlys will receive my personal data from UAB "Vilnius implantology Center Clinic" on the basis of my written request.

I have the right to withdraw my consent at any time via e-mail address [kirlys@gmail.com]. Withdrawal of my consent will not affect the lawfulness of the processing of my personal data prior to the withdrawal of consent. I have the right to exercise my rights as a data subject at any time. If I believe that dr. Robertas Kirlys processes my personal data in an unduly and/or unlawful manner, I have the right to contact dr. Robertas Kirlys itself or file a complaint with the State Data Protection Inspectorate (vdai.lrv.lt).

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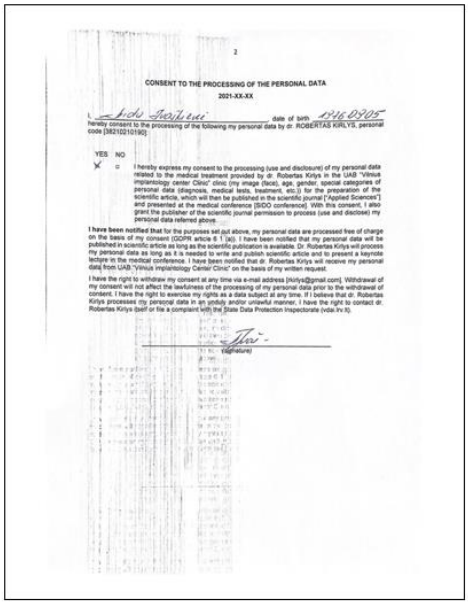

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2021-XX-XX

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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