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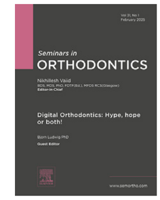

Conventional versus digital workflows for palatal TADs?

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A R T I C L E   I N F O

A B S T R A C T

Recently the feasibility of modern CAD/CAM workflows were described to manufacture insertion guides and metal printed appliances to improve the possibilities of palatal TAD anchorage. Both conventional and digital workflows are safe and efficacious and broaden the treatment options significantly. Advantages of digital workflow are that TADs and appliance can be inserted in just one appointment, more rigid appliances can be designed and a higher precision can be obtained due to the use of scanners. Disadvantages of the new digital workflow may be higher cost and more time that is needed for the incorporation of digital workflows and design of the appliances. Additionally, there is always need for a laboratory process, whilst some conventional TAD appliances can be bend and adapted directly chairside. Metal printed appliances are very rigid and not flexible and thus cannot be activated or bent easily, which may also be considered as a disadvantage compared to conventional TAD borne sliders.

TADs (Temporary anchorage devices)

For some clinicians the alveolar process still seems to be the most preferred insertion site for temporary anchorage devices (TADs).[1-4] However, orthodontists are confronted with an average loss rate of 10−30 % of alveolar mini-implants as reported in the literature.[5-9] From our clinical experience, it is not recommendable to insert buccal TADs especially in children under 15 years due to the immature bone quality in the alveolar process in young patients. In contrast to buccally inserted mini-implants, failure rate of mini-implants in the anterior palate is reported to be 1–5 %, which is significantly lower than in other regions.[9-13] In the anterior palate a superior bone quantity and quality combined with thin attached mucosa and minimal risk of tooth-root injuries can be observed.[9,11,14] Mini-implants in the anterior palate can be used perfectly for molar distalization (Fig. 1), space closure, rapid maxillary expansion and protraction, molar intrusion and alignment of impacted teeth. To allow a stable connection between palatal mini-implants and orthodontic wires and to achieve integration into the orthodontic mechanics, mini-implants with interchangeable abutments should be used.[15] In recent years, CAD-CAM techniques such as insertions guides and 3D metal printing were integrated into palatal mini-implant workflows (Figs. 1 and Fig. 2).[16-19]

Mini-Implant placement

For anaesthesia, we recommend the use of syringes with tiny needles (e.g. Citoject, Kulzer, US) and application of two paramedian depots (Fig. 3). If the patient is apprehensive about use of a needle syringe, the miniscrews can be placed using only topical anaesthetic (jelly). Pre-drilling is only recommendable if mini-implants are going to be inserted nearby the palatal suture of adult patients (Fig. 4, 2–3 mm pre-drilling depth). A TAD diameter of 2 mm or 2.3 mm and lengths of 9 mm are usually selected providing a high stability.[20-23] Palatal mini-implants can be inserted with or without an insertion guide, either manually using a contra-angle or an electrical screw-driver. The ideal zone with the lowest failure rates is directly posterior from the palatal rugae. Distally from the rugae, an area with sufficient bone volume and a thin soft-tissue layer can be detected (Fig. 5).[24,25] In this so called T-zone, mini-implants can be inserted median in adults and adolescents (Figs. 6a, and 7a) or paramedian in all patients (Figs. 6b, 7b). Very important: a paramedian insertion should be in the area of the bicuspids, because in the molar area the available bone is very thin paramedian.[25] Recently published studies have shown the advantage of paramedian over median insertion in the anterior palate, so we switched our preferred insertion site from median to paramedian over the last couple of years.[26-28] The optimal area can be identified just by intraoral inspection, a cephalogram or CBCT is needed only in special indications.

Many practitioners are not immediately familiar with the placement of implants in the anterior palate, and may be reluctant to use them. A mini-implant insertion guide potentially assist clinicians to overcome their uncertainty, providing assurance that the optimal position, length and angulation for the mini-implant has been pre-

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Fig. 1. Conventional framework for a Beneslider on two paramedian mini-implants employing a Beneplate and conventional molar bands (PSM, Germany).

Fig. 2. Digital design of a Beneslider on two paramedian mini-implants employing computer-aided design/computer-aided manufacturing–designed abutments, rails, bonded tube (on 16) and molar shell (on 26).

Fig. 3. Application of local anesthesia (Citoject, Kulzer, South Bend, Indiana) in the anterior palate.

Fig. 4. Manual pre-drilling (cooling is not needed, pre-drilling is only needed in adults).

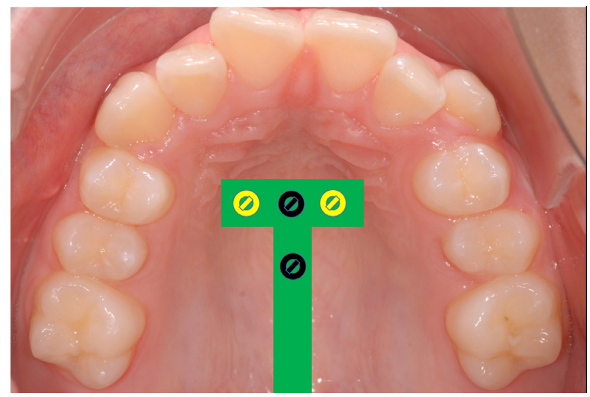
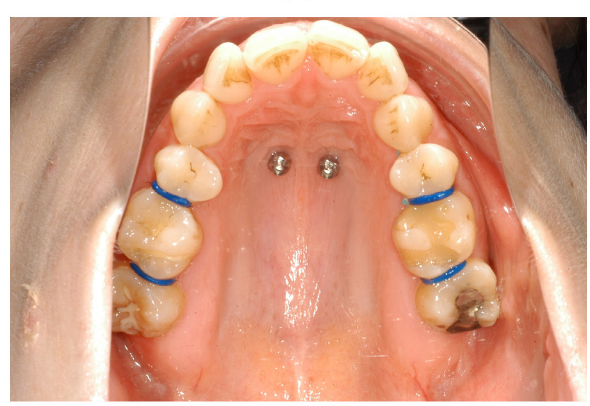


Fig. 5. Recommended Insertion Site (T-Zone) Distally from the rugae.

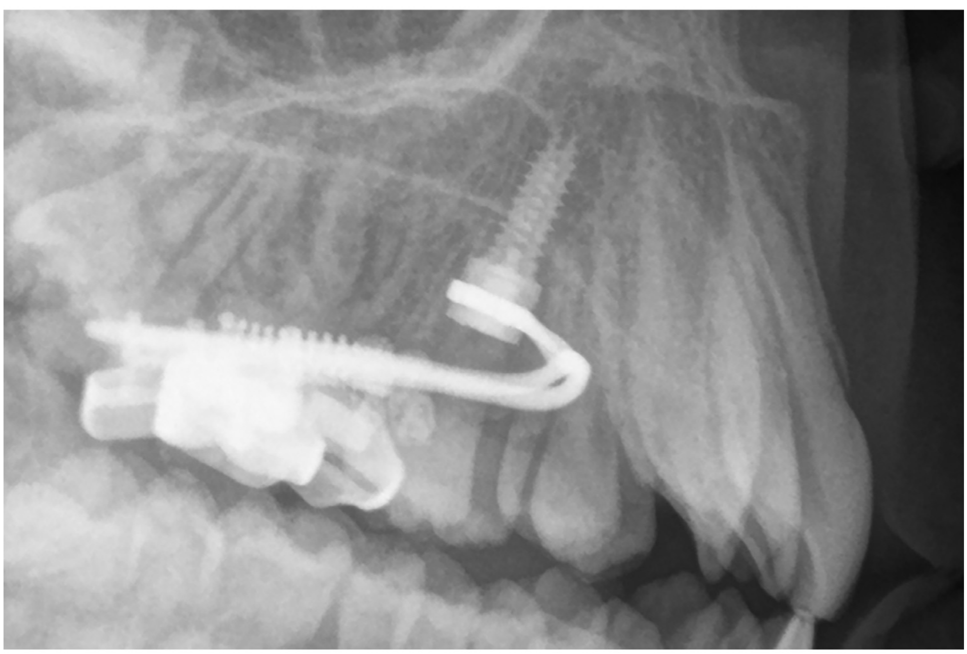
(a)



(b)

Fig. 6. A: Median insertion of mini-implants (only in adults and adolescents). B: Paramedian insertion of mini-implants.

(a)



(b)

Fig. 7. Cephalograms after insertion in the anterior palate: A: Median insertion of mini-implants. B: Paramedian insertion of mini-implants.

determined for an individual patient using a CAD-CAM platform.[16,18] For this purpose a STL (digital stereolithography file) of the maxilla is generated. This can be performed directly through the use of an intraoral scanner or indirectly by a laser scan of a plaster cast model. The STL file can be merged with either a CBCT (cone-beam computed tomography image) or a lateral cephalometric radiograph (Fig. 8). The optimal sites for mini-implant placement in the anterior palate are identified, and a virtual planning software is used to confirm the precise anatomical positions. A rapid-prototyping process produces the insertion guide which locates the ideal position of the mini-implants within the anterior palate (Fig. 9). Additionally, the orthodontic appliance can be fabricated in advance on a CAD-CAM 3d printed acrylic cast. As such, both the insertion guide and orthodontic appliance can be

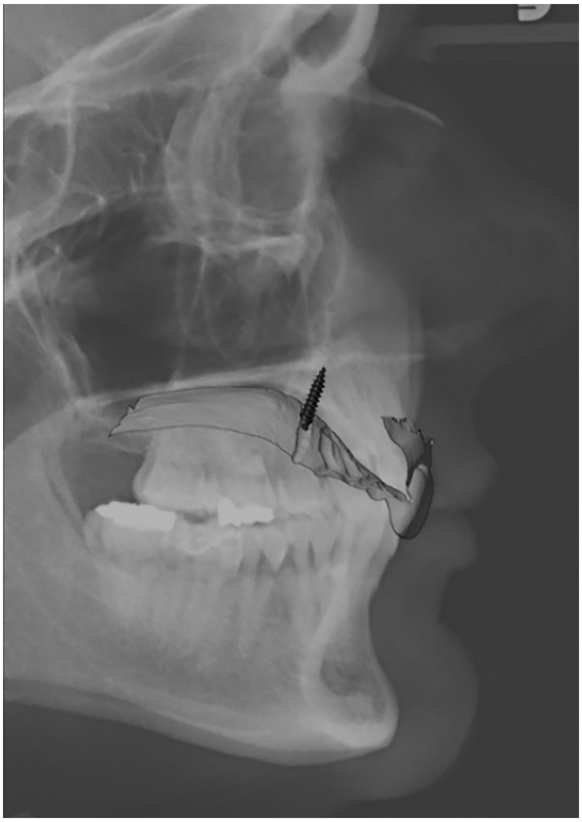


Fig. 8. Virtual Mini-implant Placement: A STL file of the upper jaw is merged with a lateral cephalometric radiograph.

pre-fabricated prior to the insertion of the mini-implants. The described process allows for the insertion of both the mini-implants and the orthodontic appliance in a single office visit (Fig. 10).[16]

Appliance installation – conventional workflow

From when orthodontists first began to use palatal mini-implants in their treatment approach, the method of connecting the orthodontic appliance with the mini-implants has garnered little review and focus. Prefabricated appliance products have been most commonly utilized (Figs. 11-14). In many cases the appliance could be adapted intraorally, which, of course, implies some chair time (Fig. 13). The alternative is to adapt the mechanics in the laboratory by taking a silicon impression and transferring the intraoral setup to a plaster cast using the impression cap and the laboratory analogue[15] (Fig. 14). For distalization and mesialization sliders, a miniplate[29] (Beneplate, 1.1 mm, Figs. 11, 13 and 14, PSM, Germany) can be adapted to the mini-implants by bending of the miniplate body as well as the wire (Fig. 13).

Clinical procedure – digital workflow

Recently the feasibility of modern CAD/CAM workflows was described to manufacture appliances using a digital workflow.[17,30,31]

The digital workflow steps are: 1. Intraoral scan. 2. Superimposition of the model with a Lateral Cephalogram or CBCT (if needed). 3. Virtual implant placement. 4. Digital appliance and insertion guide design. 5. 3D-Printing of the metal appliance and the mini-implant insertion guide. Nowadays, several software platforms are available from virtual mini-implant insertion to the design of the CAD-CAM appliances (Figs. 15,

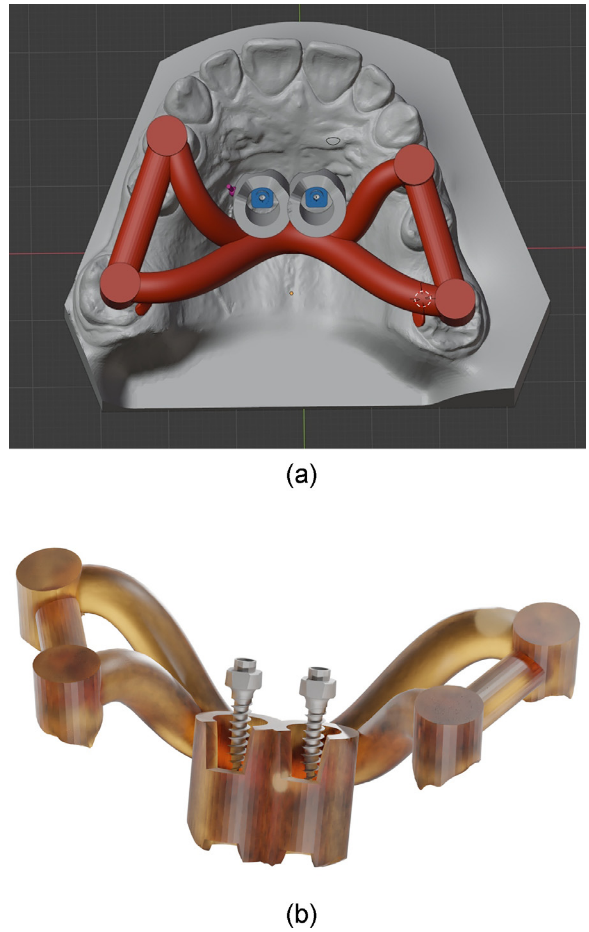


Fig. 9. A and B, Computer-aided design/computer-aided manufacturing insertion guides for ideal positioning of the mini-implants in the anterior palate.

Fig. 10. Insertion of Palatal Mini-implants Using a Computer-Aided Design/Computer-Aided Manufacturing Guide. Insertion of both the mini-implants and the orthodontic appliance in a single office visit is now possible.

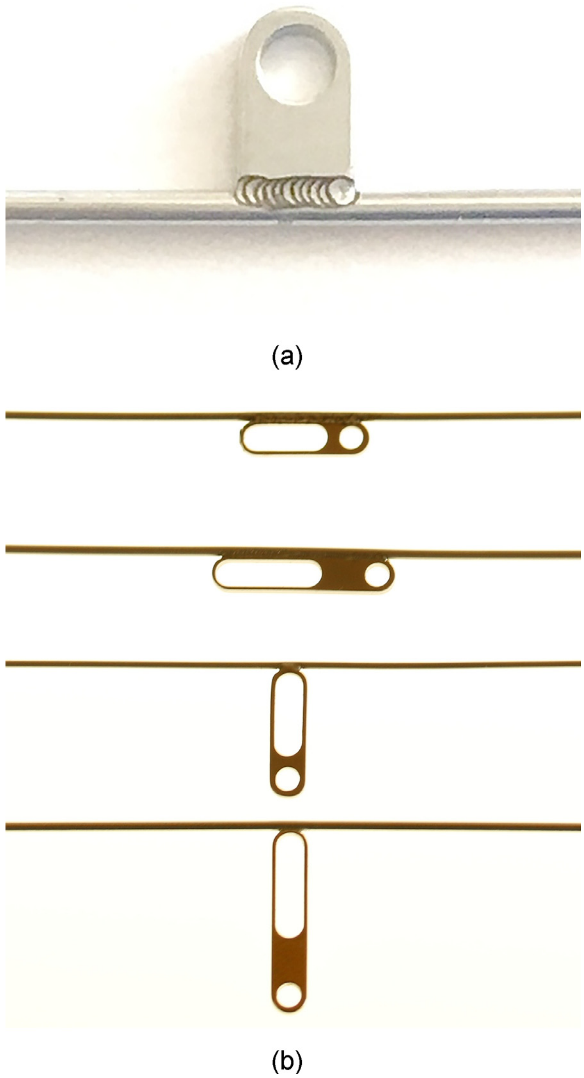


Fig. 11. Abutments for the conventional design of the supra-construction. A, Hyrax Ring abutment. B, Beneplates for median (lower) and paramedian (upper) insertion (PSM, Germany).

and 16). Digital Benesliders can be designed using virtual abutments, rails, connectors, sliding tubes and shells (Fig. 15). Molar shells are designed with a bonding gap of 0.05 mm.[30] To complete the digital workflow, insertion guides are designed to contain the information of mini-implant insertion site, angulation and insertion depths. A minimalistic design is nowadays chosen comprising a four-point contact on the patient's dentition (Fig. 15c). The final parts (Slider framework, molar shells, sliding tube, insertion guide) are exported and materialised using modern 3D-printing techniques (Fig. 15d). For production of the metallic components selective laser melting (SLM) using Remanium Star powder (Dentaurum, Ispringen, Germany) is used. The insertion guide is printed using stereolithography and biocompatible resin. These CAD-CAM procedures can be used not just applied for palatal sliders, but also for numerous variations of maxillary anchorage devices, e.g. maxillary expanders, such as the Hybrid Hyrax[17,32] (Fig. 16).

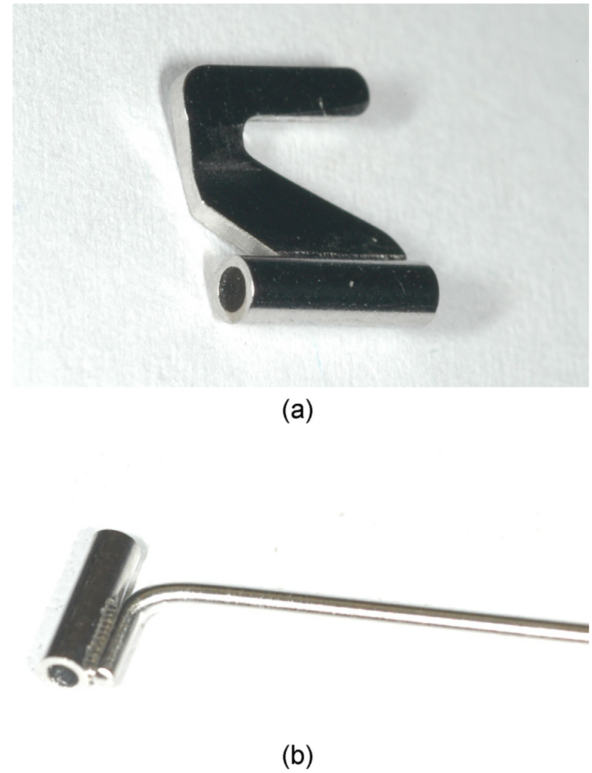


Fig. 12. Tubes for the connection of mini-implant−borne sliders with molars. A, For bands with sheaths. B, For bonding to the palatal surface.

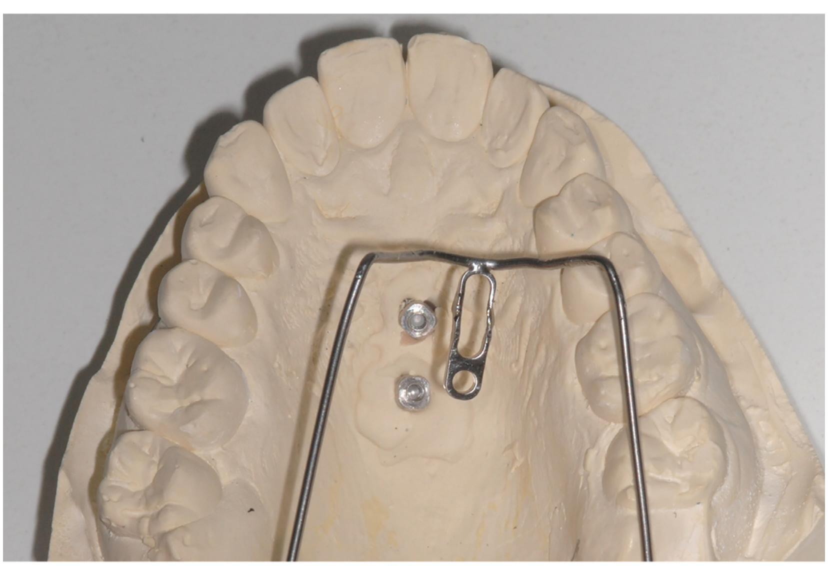
Fig. 13. Direct intraoral chairside adaptation of the framework.

Pros and cons of conventional versus digital techniques

Both conventional and digital workflows are safe and efficacious and broaden the treatment options significantly. As shown by Graf et al. the CAD/CAM workflow obviates the need for tooth separation and the uncomfortable step of band seating.[30] The full digital workflow offers the opportunity to insert mini-implants and CAD orthodontic appliances in a single appointment, making the process more economic for the patient and the doctor. De Gabriele et al. have initially described the implementation of a single appointment workflow. However, the orthodontic appliances were manufactured by conventional laboratory techniques.[18] Compared to the traditional laboratory manufacturing method of

(a)

(b)



(c)

Fig. 14. Transferring the intraoral setup to a plaster cast using an impression cap and a laboratory analogue (A) and a silicon impression (B). Adaptation of a Beneplate (PSM, Germany) on a plaster model (C).

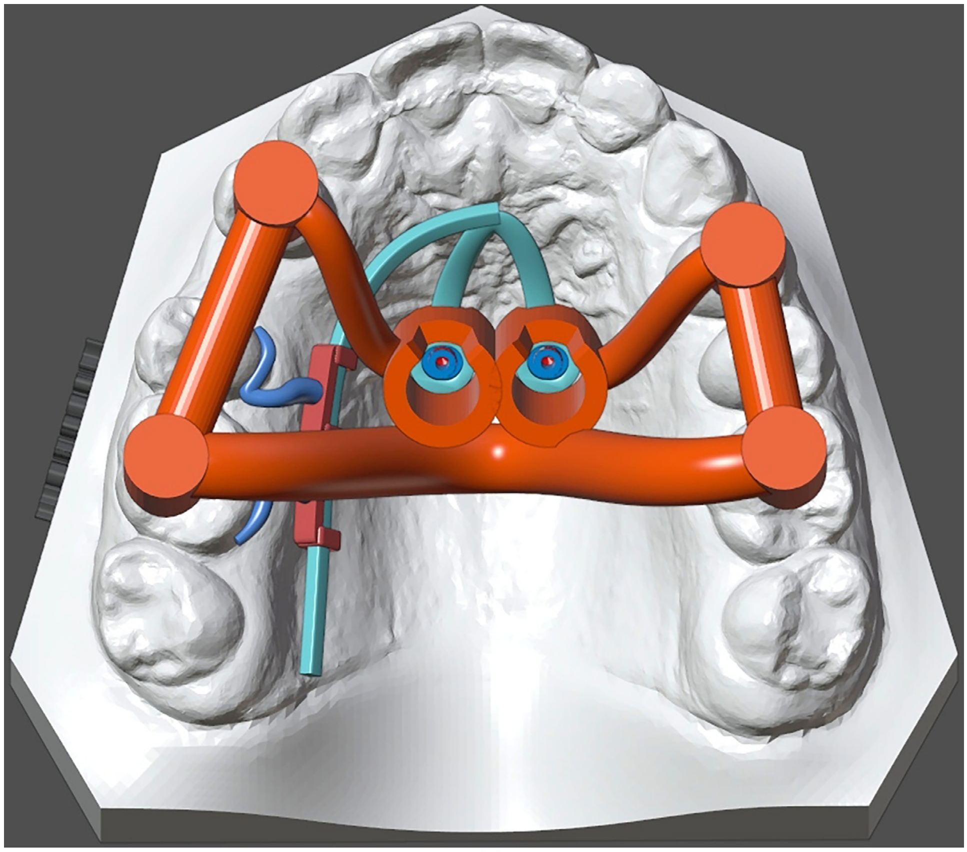
Fig. 15. A and B, Beneslider with digitally designed abutments, rails, connectors, sliding tubes, and molar shells. C and D, for a full digital workflow facilitating a one-appointment protocol, an insertion guide is produced.

palatal min-implant borne mechanics we experienced that the digital appliance design workflow enhanced appliance fitting greatly. The digital workflow eliminates possible sources of error such as:

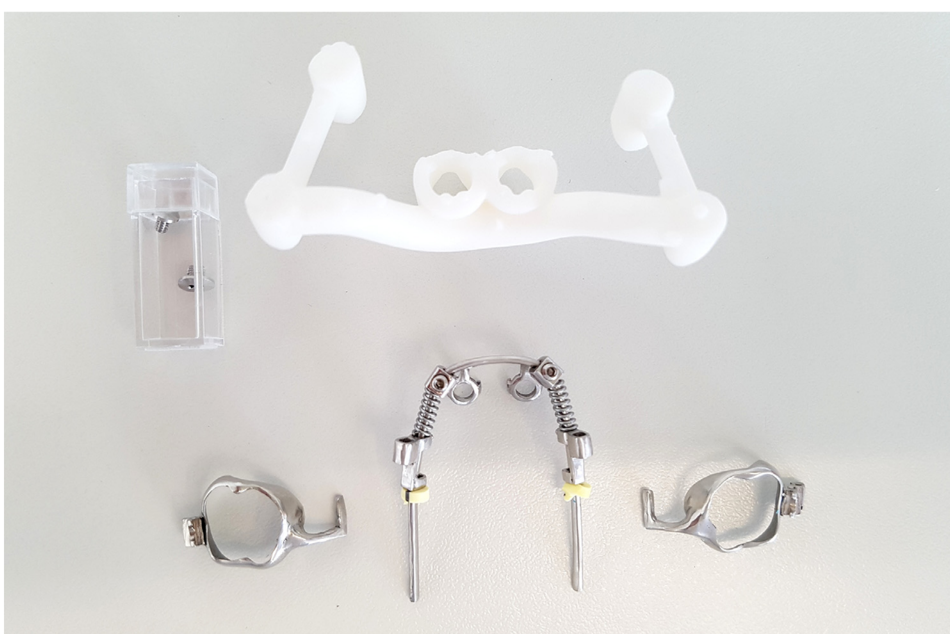
- Band transfer from impression to a plaster model
- Incorrect transfer of implant position to the dental laboratory

The digital design process offers the perspective to improve and customize the appliance design, e.g. improve the rigidity of wires when rigidity is needed, for example for maxillary expansion appliances.

Disadvantages of the new digital workflow may be higher cost and more time that is needed for the incorporation of digital workflows and design of the appliances. Additionally, there is always need for a laboratory process, whilst some conventional TAD appliances can be bend and adapted directly chairside (e.g. the Beneslider by using a pre-fabricated Beneplate preconstruction, PSM, Germany). Metal printed appliances are very rigid and not flexible and thus cannot be activated or bent easily, which may also be considered as a disadvantage compared to conventional TAD borne sliders. Last but not least, we experienced a higher failure rate of CAD/CAM bands compared to conventional bands which are retained also in the undercut area of molars.



(c)



(d)

Fig. 15 Continued.

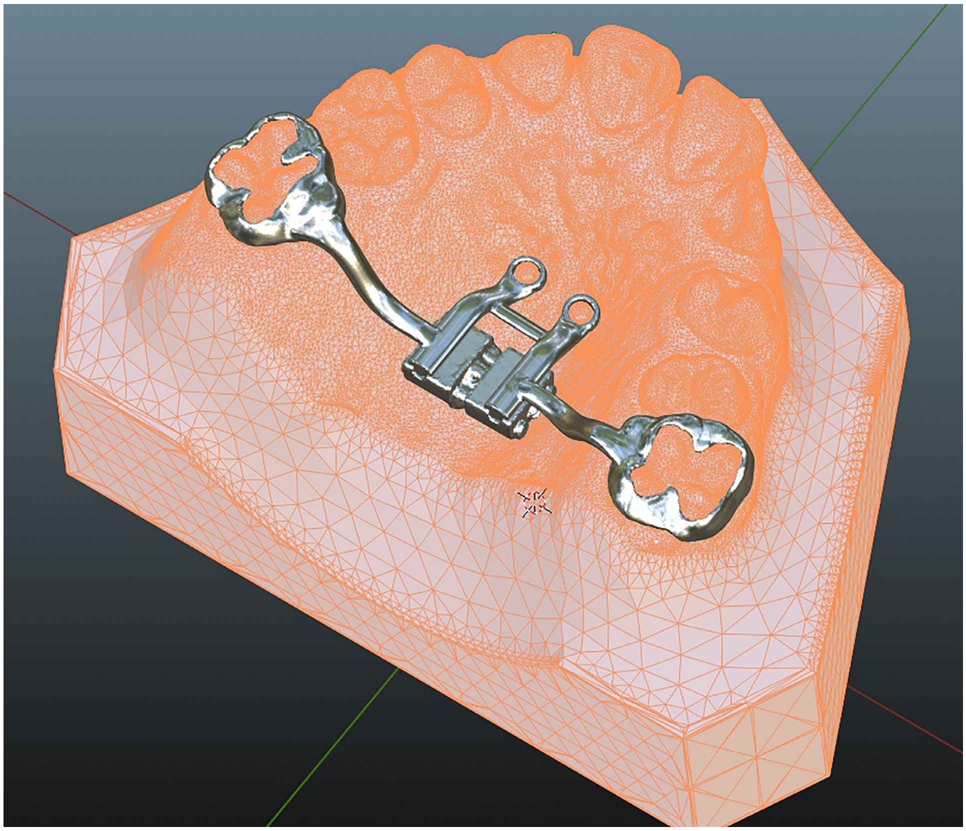


Fig. 16. Computer-aided design/computer-aided manufacturing−designed miniscrew-assisted rapid palatal expansion appliance (Hybrid Hyrax). For Class III maxillary traction, additional hooks may be added for facemask connection.

Conclusions

Nowadays, a complete digital workflow from virtual insertion to CAD/CAM design of orthodontic metallic appliances is possible. These new procedures allow mini-implant insertion and appliance fitting in one appointment. CAD/CAM design process may offer the opportunity to further improve orthodontic appliances biomechanically. Even if there are still some minor obstacles using CAD/CAM techniques, the standard procedure of using TADs will be in a digital workflow.

Patient consent

Patient consent was obtained.

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Author contributions

All authors attest that they meet the current ICMJE criteria for authorship.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Benedict Wilmes reports a relationship with Tadman that includes: board membership. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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