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Orthodontics for adults – current innovations and interdisciplinary possibilities

Introduction: At this point in time, treatment of adult patients is part of the everyday lives of orthodontists. There is no difference when determining the indication for therapy in children and adolescents: the goal is the prevention and treatment of misalignments of jaws and teeth, as well as maintaining a healthy masticatory system.

Discussion: Nevertheless, there are some characteristics that need to be taken into consideration: The biomechanics should be adjusted in accordance to the progressing loss of attachment. Simultaneously, there is a great desire for preferably subtle treatment options. Furthermore, interdisciplinary treatment concepts play a more important role in adults compared to children and adolescents.

Results: The digitalization in orthodontics resulted in new and innovative therapy options for all these requirements. Generated data records using intraoral scans offer various options in diagnosis as well as planning in order to improve treatments and patient comfort. Special orthodontic software solutions were necessary to establish individualized therapy concepts. Treatment appliances with different systems can be printed using the export of STL data and made available for orthodontists. Further advances are expected in the next few years, which makes digital orthodontics an exciting work field.

Keywords: digital orthodontics; orthodontics for adults; 3D-print; CAD/CAM restorations; interdisciplinary orthodontics

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Introduction

Orthodontics is no longer limited to the treatment of children and adolescents. At this point, the treatment of adult patients is part of the clinical everyday life of this field of dentistry. In the years 2012 to 2014, every fourth patient undergoing orthodontic treatment in the US and Canada was over 18 years old [1]; the tendency is increasing. There are a number of reasons that explain this tendency:

An increased awareness for oral health exists in today's society and tooth position is also especially important for adult patients. It is socially established that straight and white teeth are considered healthy and attractive, whereas dysgnathia can lead to negative reactions in the social environments [18].

The optimized dental supply situation in the last several decades and the demographic change leads to the inevitable increase in average age in the orthodontic practice: an aging patient collective has a higher demand to optimize the position of their own natural teeth. However, adults do not just turn to orthodontists for aesthetic reasons: From a prophylactic periodontal point of view, it is advisable for older patients to correct misaligned teeth in order to prevent changes in bone structure caused by unequal load distribution.

Even with interdisciplinary questions such as pre-prosthetic distribution or pre-surgical formation of dental arches, the dental disciplines should work hand in hand in order to achieve the best possible results for the patients.

Orthodontic treatment can be subtly designed by using established treatment methods such as lingual therapy or aligner therapy, which is desired by patients that reject a conventional therapy due to the temporary unaesthetic impairment. With the advances in digital orthodontics, new exciting approaches for individualized treatment planning and execution are available [6, 10, 11, 23].

Special requirements in orthodontics for adults

The orthodontic treatment of adult patients has underlying special features. Generally, as with any patient, a periodontal screening should be done before orthodontic treatment and the patient should be referred to a dentist if there is any demand for treatment. This is indispensable, because otherwise the orthodontic therapy contributes to a progression of periodontal destruction on inflamed periodontium [20].

Usually, there is a thicker compact bone, increased attachment loss and less vascularisation of the bone with increasing age, which can to some extent be accompanied with restriction of tooth movement. Additionally, adults more often take medications that can affect the bone metabolism and therefore also impact the orthodontic therapy (Tab. 1).

Following the attachment loss, the center of resistance of the teeth is displaced more apically, and the orthodontic forces have to be adjusted. Further anchoring measures should be taken into consideration, because periodontally weakened teeth cannot compensate for the opposing forces in orthodontic therapy anymore. Mini implants can provide remedy, and will be discussed further down in this article.

The adult patients' desire

Adult patients seek out orthodontists especially with the desire to carry out a subtle treatment in a foreseeable time period. The lingual multi bracket therapy offers patients a very popular alternative to vestibular braces. Tooth movements can be carried out efficiently in all 3 spatial planes using a completely individualized apparatus (Fig. 1–3).

By establishing aligner therapy, orthodontists were given another tool to reach the desired treatment result step-by-step in a gentle manner. Nevertheless, it shall be noted that a selection of suitable patients as well as the dentists' experience with the system are imperative for successful treatment using aligners.

Current innovations in orthodontics

In order to meet the desire of adult patients, digital technologies are useful to carry out accurate and individualized planning. Digital orthodontics consists of 3 components:

1. Scan system (intraoral scanner or model scanner)
2. CAD software
3. 3D-print

Scan systems

The basis for a digital workflow is always a three-dimensional data set, usually generated by an intraoral scan. If no intraoral scanner is available, a model scanner can always be used as well. Different scan systems have been established for a few years in orthodontics and contribute to drive out the conventional impressions further and further. The precision of powder-free intraoral scans complies with that of the classic impression [13], however, it offers significantly greater patient comfort.

CAD software

This generated data set can then be imported into a suitable CAD-soft-

Figure 1–3 Treatment of an adult patient with a complete individualized lingual applicance

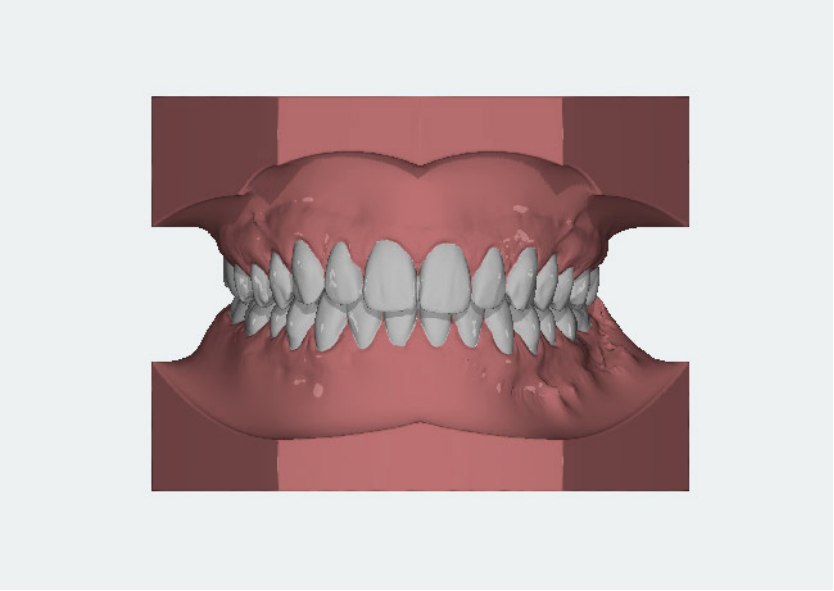


Figure 4 Segmented digital model after intraoral scan (3Shape TRIOS 3)

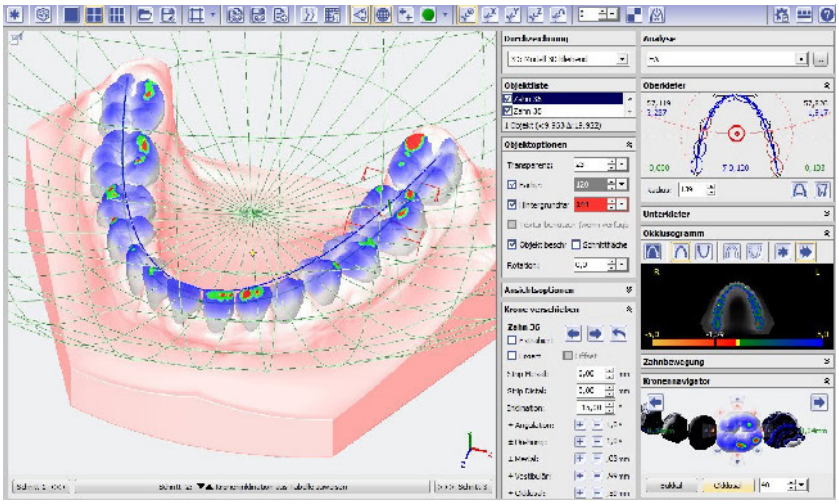


Figure 5 Orthodontic analysis of a digital model using the orthodontic software OnyxCeph^{3TM}

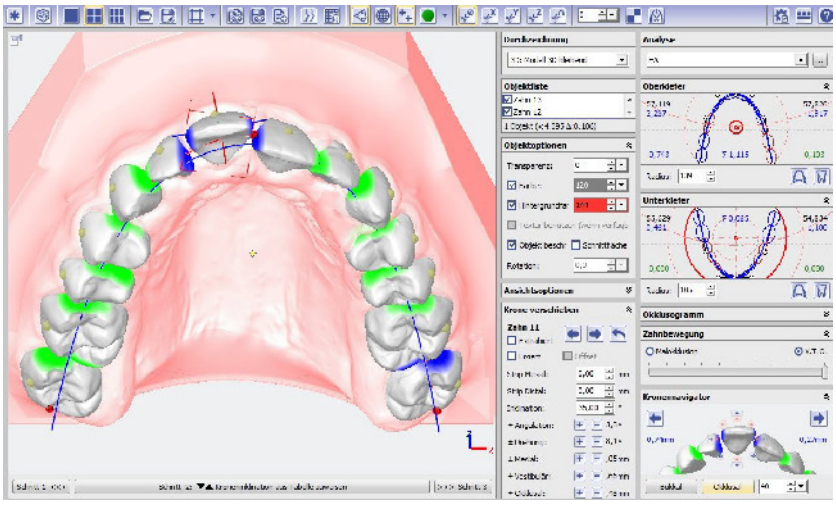


Figure 6 Creation of a digital set-up using the orthodontic software OnyxCeph^{3TM}

ware that takes care of further processing (Fig. 4). The all-digital procedure of the diagnosis, the planning and the subsequent implementation of the therapy is sketched out below and the advantages of digitalization are shown.

In our clinic we use the software OnyxCeph^{3TM} (image instruments). The workflow in digital orthodontic diagnosis includes digital photography, digital x-rays and the digital impressions mentioned above.

A full evaluation of patient documents can be done based on the generated data and then has to be supplemented with a clinical examination. The intraoral and extraoral images as well as the cephalometric x-rays can be measured and analyzed on a computer. Also the three-dimensional model can be evaluated via software (Fig. 5). Studies show that the accuracy of digital models is equal to the conventional evaluation of plaster models and sooner or later will depict the new gold standard in orthodontic diagnosis [17].

When diagnosis is completed and a type of therapy has been chosen, it can be planned and designed digitally. Lingual therapy and aligner therapy belong to the subtle treatment methods that are preferred by adult patients as described above. These usually assume a set-up which simulates the desired final position of the teeth. In the past, the well known and complex manual steps using a saw-cut model was necessary.

This is now digitally possible in a substantially precise and effective approach (Fig. 6). Teeth can be individually segmented and subsequently moved freely in the spatial planes according to the desired target position using the appropriate software.

In lingual therapy, individualized arches can be calculated using the set-up produced specifically for the patient. These can be manually bent using a printed drill template. Alternatively, the arch geometry in the CSV format can be transmitted to a bending robot, which leads to a reduction in time and increase in precision. The therapeutic transversal expansion of dental arches depicts a risk in stabilization of orthodontic

Type	Substance	Appearance/ Application	Effects	Impact on bone and tooth movement
Medication	NSAID (Aspirin, Ibuprofen)	Analgesic, anti-inflammatory	Bone resorption ↓	Tooth movement ↓
	Paracetamol	analgelsic	No effects	No impact
	Bisphosphonates	Osteoporosis, cancer treatment	Bone resorption ↓	Tooth movement ↓
	Insulin, Metformin	Diabetes mellitus	Bone stabilization ↑	Tooth movement ↓
	Vitamin D	Pregnancy, breastfeeding period, depressions	Bone resorption ↑	Tooth movement ↑
	Eicosanoids (prostaglandins, leukotrienes etc.)	mediators	Bone resorption ↑	Tooth movement ↑
	Flouride	Osteoporosis, caries prophylaxis	Bone resorption ↓ Bone mass ↑ Bone density ↑	Tooth movement ↓

Table 1 Medications and their effect on the bone and tooth movement
(Fig. 1–16; Tab. 1: L. Brämswig)

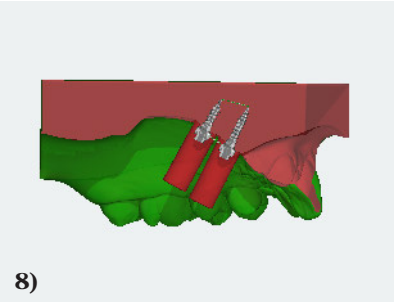
treatments [22]. First initial data show that a more stabilized tooth position can be achieved following individualized therapy [Wolf et al., submitted].

Clinical expertise is indispensable for digital planning of aligner therapy in order to assess limits of movements and plan helpful tools such as attachments correctly. Furthermore, in many cases an additional anchoring is required. Should this anchoring demand be maximal, a skeletal anchoring in the form of mini implants (TAD; temporary anchorage device) can be chosen. Because of this, tooth movements can be executed that usually can only be carried out with severe side effects. Examples of this are mesial and distal movements of molars, intrusions of individual elongated teeth, mass retractions and distractions of individually impacted teeth [3].

Ideally, the insertion of such a TAD is planned digitally. Depending on the intended application, the mini implant must be inserted in another region. Anatomic structures in the immediate topographic surroundings such as roots of teeth, inferior alveolar nerve and palatal artery have to be spared.

In order to guarantee this, a drilling template can be used. These can be manufactured conventionally in the lab or using CAD/CAM procedure. For this, an x-ray is super-

Figure 7 Superimposition of intraoral scans of the upper jaw with a cephalometric x-ray



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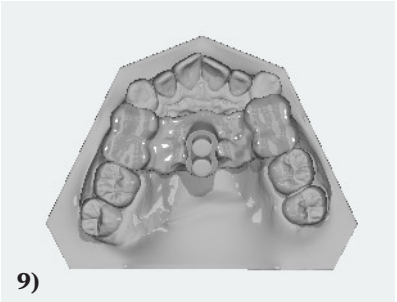

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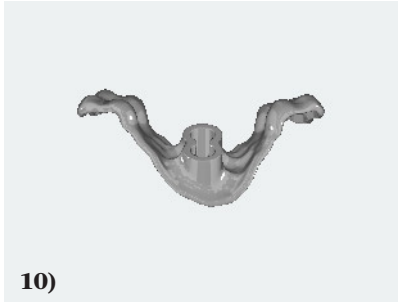

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Figure 8–10 Digital positioning of the mini implants with subsequent design of the drill template

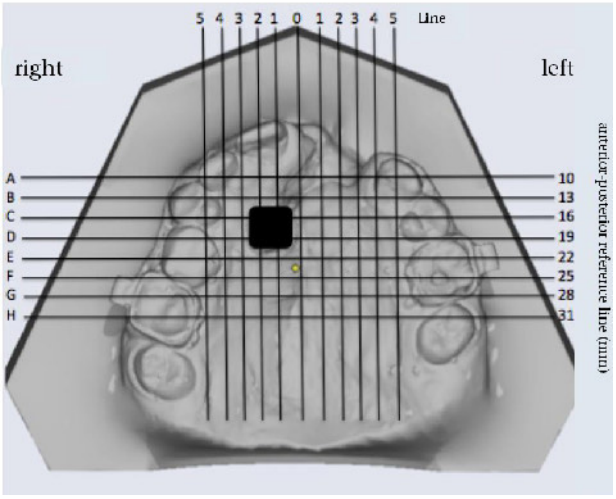


Figure 11 Best possible place of insertions for mini implants on the unaffected side

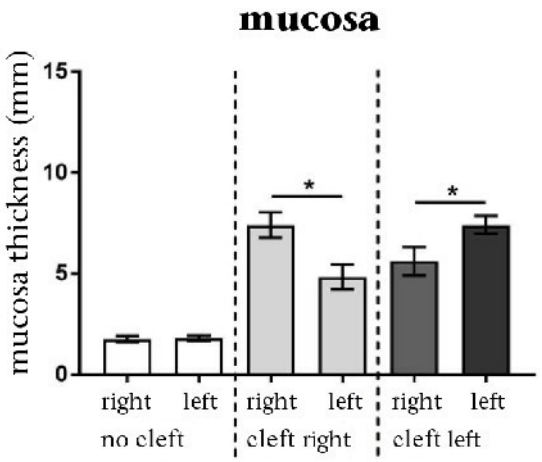


Figure 12 Small mucosa thickness in non-cleft patients in comparison to cleft-patients

imposed with the intraoral scan (Fig. 7). For palatal mini implants a cephalometric x-ray is usually used. If a TAD is inserted interradicular, a CBCT (cone beam CT) is required for the superimposition process. With this, an accurate positioning of the mini implants can be planned digitally under consideration of the immediate anatomic structures. As soon as the desired position and angulation of the mini implant is determined, a separate model is generated that defines the direction of insertion. It can then be used to design a drilling template in the desired extent (Fig. 8–10).

Using a CAD/CAM-drilling template guarantees better control during insertion and reduces the risk of deviation of the planned path of insertion, especially with inexperienced practitioners [2].

Difficult anatomic structures are another indication for a CBCT while planning mini implants.

In our own investigations we were able to show significant superimposition of mucosa of the anterior palate in patients with unilateral cleft lip and palate. The best region of insertion on the affected half of the jaw is the transition of premaxilla and maxilla [14] (Fig. 11 and 12).

A combination of mini pins and aligners has been proven to be clinically practical and therefore broadens the indication spectrum of aligner treatments in selected cases [21].

Digital tools are available for the traditional vestibular bracket treatment. The correct positioning of the brackets at the beginning of the treatment have a significant influence on the orthodontic treatment success. The conventional tooth banding of the patient is usually done adhesively on the patient directly, where every bracket is placed on each tooth individually, positioned, and then cured. Alternatively, transfer trays can be manufactured to transfer into the patient's mouth. This requires a previous laboratory process, however, it offers advantages for patient and practitioner by reducing chair time. Studies could also show that indirect adhesion guarantees a more precise bracket positioning in the vertical plane [12].

Meanwhile, a transfer tray such as this can also be planned and designed digitally. The basis here is also a segmented model via software that simulates the roots of teeth. Based on the axis of the tooth, brackets can be positioned correctly virtually. On top of the correct position of the bracket, a positioning template can be designed, saved as an STL data set and submitted to the printer (Fig. 13). The brackets can be placed In the CAD-CAM drilling template and transferred indirectly into the patient's mouth. Initial investigations from our clinic show that a good transfer of the digitally planned bracket position can be achieved.

The planning and design of individualized metallic devices is another option to design treatment devices using a suitable software offer. A patient-specific adjustment of treatment devices was already possible before, however, the usage of pre-fabricated goods in anatomic conditions that vary widely from the norm is always associated with restrictions.

Digital methods also show efficient solution approaches, so that, ideally, delicate devices can be ad-

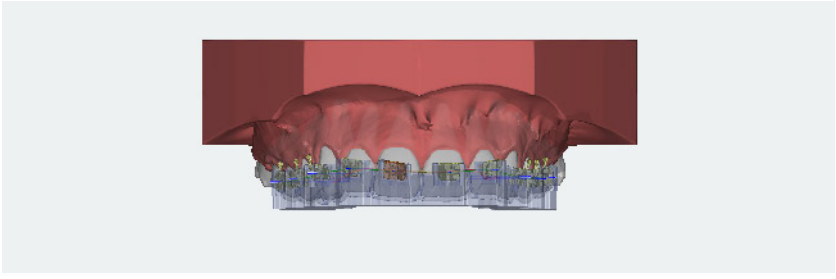
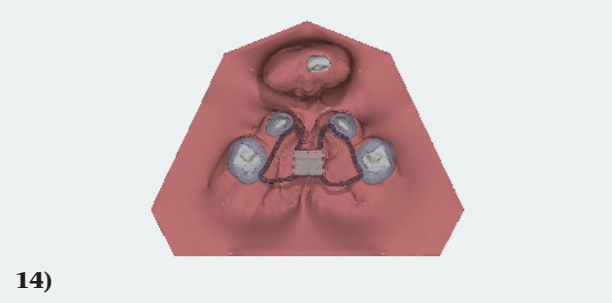


Figure 13 Digital positioning of brackets with subsequent design of a transfer tray



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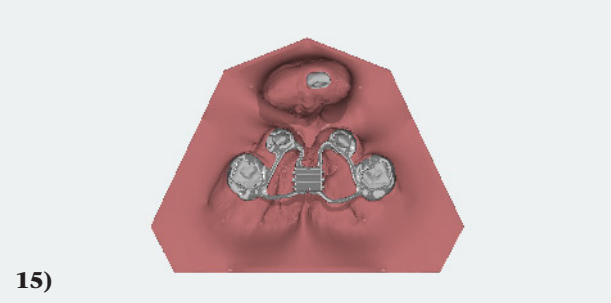

15)

Figure 14 and 15 Individualized design of an appliance for palate expansion in a patient with double-sided cleft lip palate

justed individually and subsequently manufactured (Fig. 14 and 15). Besides the advantage of the highly precise fit, it can also lead to shortened appointments because the separation for conventional bands is not necessary in digitally produced devices.

3D-print

All previously depicted procedures of therapy planning and design of treatment devices via a CAD software lead to a 3D print. Sprockets for aligners, drill templates for mini implants or bonding trays for bracket transfers can be saved as STL data sets and submitted to a printer. Depending on the indication there are various procedures available, and in dentistry especially the SLA (stereolithography), DLP (Digital Light Processing) and the FDM print (Fused Deposition Modeling) have become established. Resin-printers can usually impress with shorter printing times, whereas the post processing in form of alcoholisation and post-curing of filament printers is omitted. Orthodontic questions can be achieved with any of the systems [5, 9], even though further advances can be expected in the next few years. Another form of the 3D print is the SLM Printing (selective laser melting), which can be used to manufacture metallic devices. The acquisition of a printer like that is currently extremely cost-intensive for the single practice, but an external printer on larger labs is already provided. In an additive production process the material to process in powder form is melted layer by layer. A cobalt chrome alloy is usually used in orthodontic devices.

Interdisciplinary orthodontics

Besides digital innovations in orthodontics mentioned above, there are also benefits offered in the interdisciplinary exchange. Dental colleagues can simultaneously consult on corresponding questions in their workspace using a digital model without having to refer to the plaster model.

Not only the purely orthodontic treatments, but also interdisciplinary treatment of patients offer interfaces that have led to treatment progress thanks to digital technologies.

Thus, operation splints were designed and subsequently printed using a 3D-data set in a CAD/CAM procedure. Studies could show that an equal or higher precision in production was achieved in less time compared to conventional splints [7, 8, 24, 25].

Furthermore, a VTO (visual treatment objective) can be created in patients treated by orthognathic surgery in order to set up a pre-therapeutic prognosis for the soft tissue profile after corrective osteotomy. This tool can be used for demonstration and patient communication, however, it should be implemented carefully to not incite unrealistic expectations [15]. Such a VTO can be generated either using two-dimensional or three-dimensional data sets, where the latter produces more precise prognoses [19].

In addition, in another working field between surgical dentists and orthodontists, there are new and exciting approaches to improve care of patients. In patients with agenesis or premature tooth loss, orthodontic space closure is not always the first choice. Prosthetic restorations, which definitely yield great results, are often needed to completely close such spaces. In selected cases, the autogenous transplantation of a tooth into the aplastic region offers a great predictable therapy option [16]. If a three-dimensional x-ray is present, that tooth that is to be transplanted can be deducted and printed pre-operatively using a DICOM data set of the CBCT. The generated template is then tried on in the region that needs to be treated during the surgery. This has the advantage, that the bone can be prepared optimally, which is accompanied with little bone loss. Also, the extra-alveolar time of the tooth as well as the damage of PDL cells is minimized during the operation, which leads to an improved prognosis of the treatment [4].

There are also new paths of treatment seen in other dental treatments. If a dentist wishes to treat

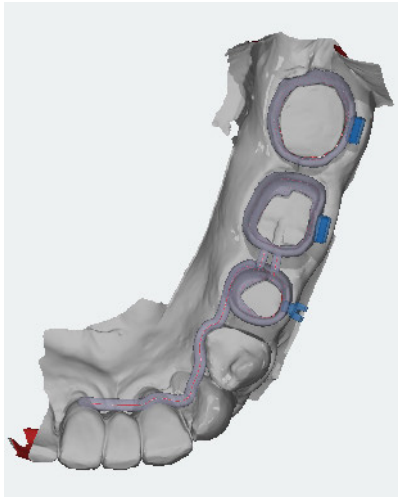

Figure 16 Individualized straightening appliance to extrude the tooth 37 for subsequent restoration of a subgingival defects

subgingival defects of a tooth by extruding that tooth, a strong anchoring should be chosen in patients that are not banded in order to avoid unwanted side effects on neighboring teeth. Through the SLM printing, the rigid and also delicate apparatus as described above can be designed with the desired tooth movements without loss of anchoring (Fig. 16). After successful extrusion the dentist can proceed with the treatment of the tooth.

Conclusions

Using digital treatment methods, various new approaches are given in orthodontics that facilitate and improve therapy. Moreover, new ranges of treatment appeared that could be used in interdisciplinary questions and therapy planning and therefore contribute to treatment success. Thanks to the advances in 3D-printtechnology it will lead to exciting innovations in the future.

Conflicts of interest

The authors declares that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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