

Werner Schupp, Julia Funke, Julia Haubrich, Wolfgang Boisserée

Follow-up treatment after initial splint therapy



Werner Schupp

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Splints as therapeutic treatment instruments in temporomandibular disorder patients are widely accepted. The combination of splint therapy and aligner orthodontics not only provides comfortable and almost invisible treatment but also constitutes a powerful instrument for the orthodontic treatment of the temporomandibular disorder patient. To this end, precise knowledge of the temporomandibular joint, temporomandibular disorders and treatment using removable and fixed splints is indispensable. The two-phase treatment and the combination of fixed splint and aligner transform occlusal splint therapy into a permanently stable occlusion with physiological posterior vertical support.

Introduction

An occlusal splint can be both a therapeutic instrument and a diagnostic tool:

Werner Schupp, Dr. med. dent.
Private Practice, Cologne, Germany

Julia Funke, Dr. med. dent.
Private Practice, Cologne, Germany

Julia Haubrich, Dr. med. dent.
Private Practice, Cologne, Germany

Wolfgang Boisserée, Dr. med. dent.
Private Practice, Cologne, Germany

Correspondence to: Dr Werner Schupp, Fachpraxis für Kieferorthopädie, Hauptstraße 50, 50669 Köln, Germany. E-mail: schupp@schupp-ortho.de

- to determine whether the occlusion is the cause or only a cofactor in the development of a complaint
- for the determination of the physiological jaw relationship before definite measures for occlusal correction are taken.

A re-evaluation of the performed functional therapy is carried out approximately 3 to 6 months after the start of the splint therapy. The focus lies on the occlusal analysis and the question of the therapeutic effect of the performed corrections of the occlusion. If orthodontic treatment is indicated, it is carried out by means of aligner orthodontics¹.

Re-evaluation of functional therapy

On the basis of a renewed, repeated dental functional examination 3 to 6 months after initiation of the splint therapy, a comparison can be made to the initial situation. The examination procedure consists of the following:

- Anamnesis and comparison of the graduated symptoms that were represented by the patient in the pain questionnaire.
- Examination of the craniomandibular system:
 - contacts in therapeutic occlusion (splint)
 - palpation of the masticatory muscles and cervical musculature
 - palpation of the temporomandibular joints (TMJ), motion check, joint play tests.

- Examination of the relationship between occlusion and the musculoskeletal system.
- Occlusal diagnostic:
 - A new mandibular dental cast is mounted in the current centric position determined by the splint to the maxillary cast of the initial situation. Thus, a conclusion can be drawn on the therapeutic jaw position, which in the course of the splint therapy has been reached in cooperation with manual therapy.
 - A renewed occlusal analysis is performed and compared with the initial situation.

Possibilities of follow-up treatment

No therapy success after splint treatment

If the treatment has not been successful, the occlusal therapy should be discontinued as soon as possible, and after 6 months at the latest.

The treatment of the occlusion has no therapeutic effect:

- if the cause of the temporomandibular disorder (TMD) is not only in the occlusion
- if a psychological part of the disease is predominant
- in cases of a primary joint disorder, the symptoms may be worsened by the splint therapy and a surgical intervention might be necessary.

Treatment success after splint therapy, no further occlusal therapy necessary

If the treatment with splints was successful and no further occlusal therapy appears to be necessary, the following applies. In some cases, the splint therapy reveals only marginal occlusal changes, so no orthodontic and/or prosthetic treatment is required. To wear the splint only at night may be sufficient. The splint needs to be extended to cover the incisors for the retention phase, otherwise unwanted side effects, such as intrusions of molars and premolars, can occur. A re-evaluation is carried out after 6 months. If the pain recurs, the patient should immediately start to wear the splint again and present him/herself to the dental practice in order to discuss further therapy.

Further occlusal therapy

If the occlusal therapy was successful and a further stabilisation of the occlusion is necessary, the following applies.

Depending on the situation, further stabilisation takes place by subtraction (by means of grinding), by correcting tooth positions (orthodontics) and/or by means of prosthodontics/restoration (change of the tooth form or reconstruction of teeth). Frequently, subsequent treatment is necessary in order to permanently stabilise the therapeutic occlusion and release the patient into a state of therapeutic freedom. This follow-up treatment must be performed in the therapeutically adjusted condylar position. This entails some complications and requires experience and training.

The basis for further planning is the functional diagnostics and model assembly in re-evaluation, therefore the continued occlusal treatment depends on the individual situation¹. For orthodontic follow-up, it is important to transfer the mandibular position in a 1:1 ratio, as the position was previously verified with the splint, i.e. the tested position ensures that the patient is without complaints. If the vertical height is blocked too far by the removable splint, an improved or corrected therapeutic overbite should be established, with non-removable splints that in turn are tested for approximately 4 weeks. If the patient remains symptom-free, the splints should be maintained for the orthodontic treatment. With the aid of the splints it is possible to hold the mandible in the painless and correct position^{2,3}.

The orthodontic treatment procedure in detail

Orthodontic therapy with fixed splints has become a common treatment procedure and was described by the present authors in 1993⁴. Cozzani et al² reported orthodontic treatment in combination with a therapeutic splint in 2003². The orthodontic treatment starts with a therapeutic splint to establish the physiological relation of the TMJ. After this has been achieved, the second orthodontic phase follows, during which the new maxillomandibular situation is stabilised occlusally. During this second phase, teeth are moved and the occlusion is stabilised while the patient continues to wear his/her therapeutic splint.

Fixed occlusal mini-splints were described in 2004 by Crismani et al³: "After the craniomandibular therapy and before the orthodontic therapy, mini-splints are bonded. These splints are necessary in order to keep the mandible in a pain-free position"³.



Fig 1a to c Initial situation after 6 months' treatment with COPA by the dental practitioner.



Fig 2a to c COPA in situ (designed by the dental practitioner). The patient is now pain-free.



Fig 3a to d Start of treatment in the orthodontic office. The COPA is separated into an anterior and a posterior part. The posterior part is prepared for bonding without being altered in the occlusion. The COPA onlays are then bonded to the mandibular molars with a thinly flowable bonding agent.

The use of craniomandibular orthopaedic positioning appliance (COPA) onlays in combination with aligner treatment and combined extrusion of premolars and molars is described in depth in the following case reports. It is well documented that the orthodontic correction of the curve of Spee by means of extrusion of the posterior teeth is stable^{5,6}.

The process is shown in detail in Figs 1 to 13, with the treatment plan in two phases.

Phase 1 (Figs 1 to 10)

- Correct malocclusion of anterior teeth (15 to 25 and 35 to 45).



Fig 4a to c Start of aligner treatment with directly bonded attachments and COPA.



Fig 5 COPA onlays were placed. Scan of the intraoral situation at the beginning of treatment.



Fig 6a and b ClinCheck phase 1 initial full occlusal contact on maxillary molars to the COPA onlays.

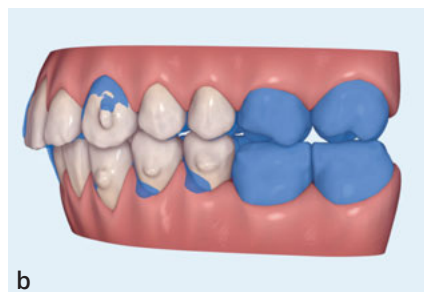
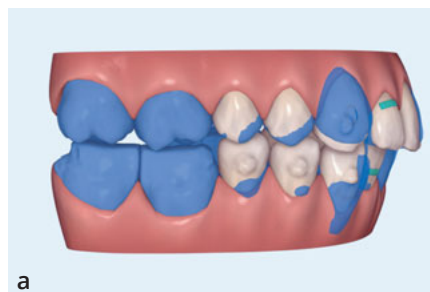


Fig 7a and b Superimposition of ClinCheck phase 1: the molars have not moved, incisors are intruded, canines and premolars are in contact.



Fig 8a to e End of phase 1 with corrected occlusion of teeth 15 to 25/35 to 45, premolars are in a full occlusal contact. The COPA onlays are debonded. Horizontal rectangular attachments are necessary on the mandibular molars.



Fig 9 Mandibular retention splint made of Duran 0.75 mm (Scheu-Dental, Iserlohn, Germany) or Imprelon 0.75 mm (Scheu-Dental) is needed until the first aligner of phase 2 can be inserted.



Fig 10 Scan of the intraoral situation at the end of phase 1.

- Do not move the molars, as they keep the mandible and thereby the condyles in a pain-free position.
- Extrude mandibular premolars to full antagonist contact.
- Intrusion of mandibular canines and incisors in most cases.
- Plan attachments if directly bonded attachments are not to be used (these are necessary for tooth extrusion).

Phase 2 (Figs 11 to 13)

- Extrusion of mandibular molars to full antagonist contact.
- Every other movement is possible.
- Horizontal rectangular attachments are necessary for the extrusion of mandibular molars.

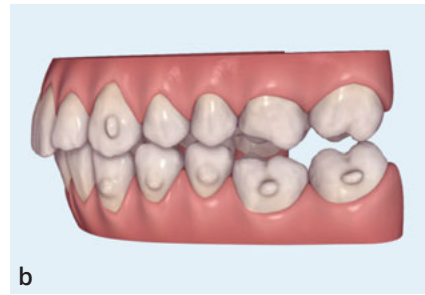


Fig 11a and b ClinCheck phase 2: initial situation with full occlusal contact of canines and premolars. COPA onlays were debonded, and attachments were placed on the molars.

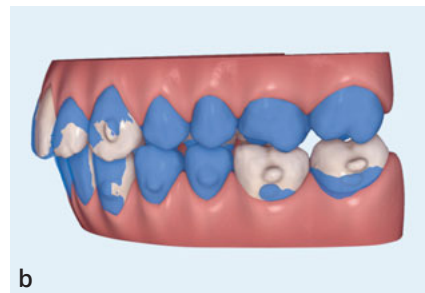
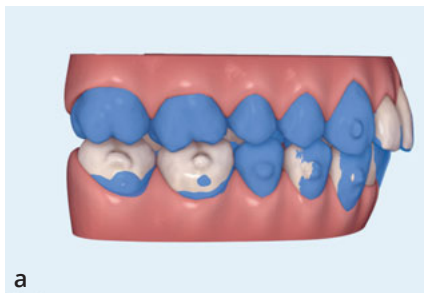


Fig 12a and b Superimposition of ClinCheck phase 2: The molars should end in full occlusal contact. The maxillary left first molar (tooth 26) needs a new restorative treatment after orthodontic therapy.



Fig 13a to c Final result with occlusal stops on premolars and molars in the same vertical dimension originally defined by the removable splint (COPA).

Patient 1

A 28-year-old woman had suffered from bilateral TMJ pain with crepitus and radiating pain to the ears for 4 years. She also complained of regularly appearing neck pain and had suffered from back pain for 6 years. For this purpose, the patient had received tramadol as a long-term medication from her general practitioner. From the orthopaedic side, scoliosis had been diagnosed in childhood. In her youth, a fixed orthodontic treatment was performed *alio loco*. In this context, the maxillary first premolars and one mandibular first premolar were removed for orthodontic treatment reasons.

Diagnostics

The functional examination revealed a connection between the patient's complaints and the occlusion. The main symptom was a bilateral TMJ compression in habitual intercuspation (HIP), which was triggered by an early contact in the anterior region and lack of support in the posterior region in centric jaw relation (Fig 14).

This type of occlusal deviation leads to a retral displacement of the mandible on the functional surfaces of the teeth during habitual jaw closure, whereby at the same time the condyles of the TMJs in the glenoid fossa are forced retrally and cranially.

In the examination of the temporomandibular system, a bilateral pressure pain of the bilaminar zone and the clearly retrally palpable condyles could be detected as a

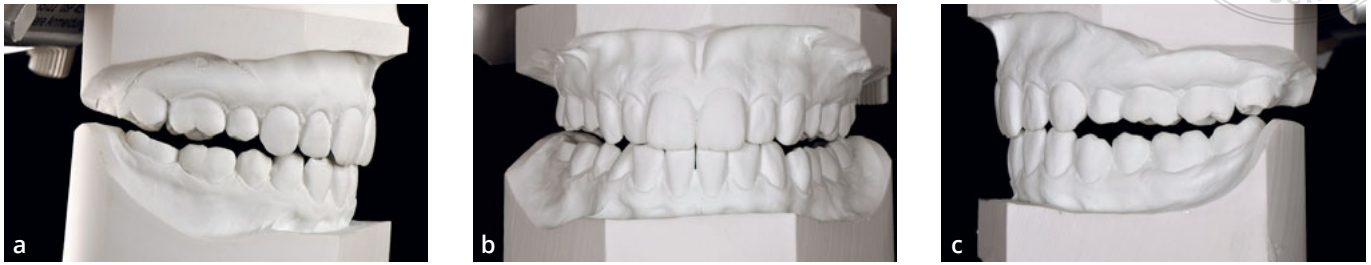


Fig 14a to c The centrically mounted casts show that in the physiological jaw relationship only anterior contacts exist, while the posterior teeth showed considerable non-occlusion.

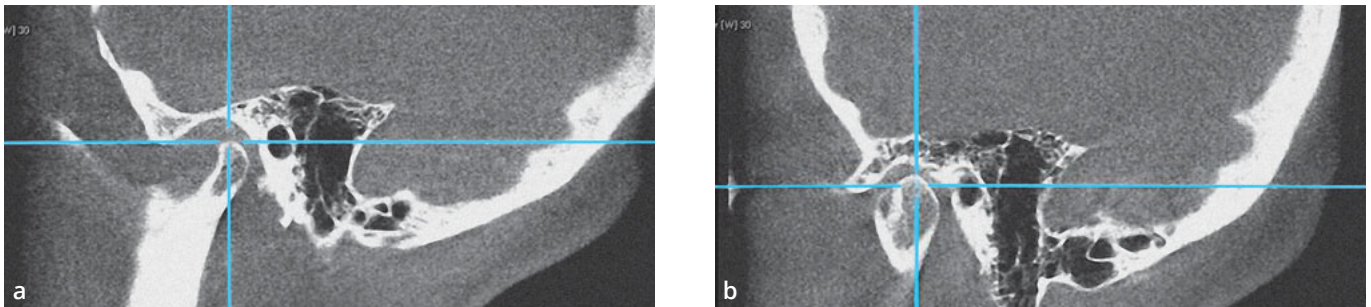
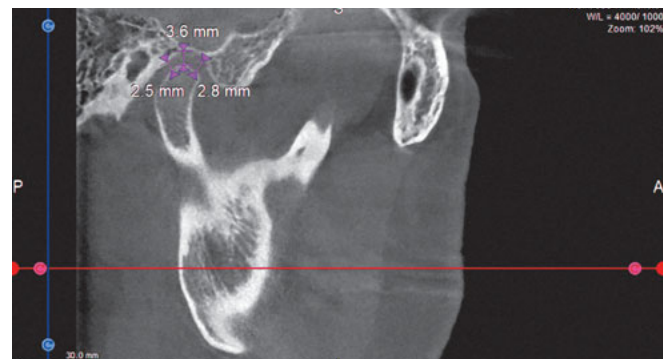


Fig 15a and b The CBCTs of the right and left temporomandibular joint confirm the findings of the temporomandibular joint compression.

Fig 16 For comparison, a physiological temporomandibular joint situation is shown. The condyle is positioned in the middle of the fossa. There is a clearance of 2.8 mm anteriorly and posteriorly, 2.5 mm posteriorly and 3.6 mm cranially¹⁷.



diagnostic correlation for a bilateral TMJ compression. Due to the TMJ pain, a cone beam computed tomography (CBCT) scan of both TMJs was made for differential diagnostic reasons. This confirmed the retral displacement of both condyles in HIP (Figs 15 and 16).

Orthodontic treatment

Following successful completion of the occlusal splint therapy (Figs 17 and 18) by the dental practitioner (WB), the patient was practically pain-free and long-term medication

was discontinued. The occlusal contact distribution remained the same for several weeks, so that orthodontic therapy could be performed by means of a combination of fixed splints and the Invisalign system (Align Technology, San Jose, CA, USA)⁷⁻¹⁰. For the orthodontic follow-up treatment, the mandibular jaw position was taken over in a 1:1 ratio, as it had previously been adjusted with a splint, i.e. the tested position, in which the patient is symptom-free.

With the onlays cut directly out of the splint, the mandible was kept in the pain-free and correct position.

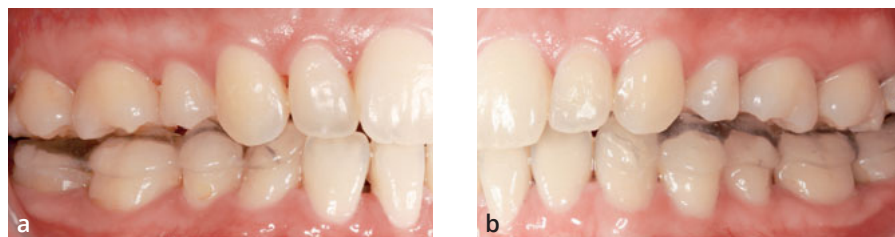


Fig 17a and b The inserted splint for the physiological balancing of the occlusion.

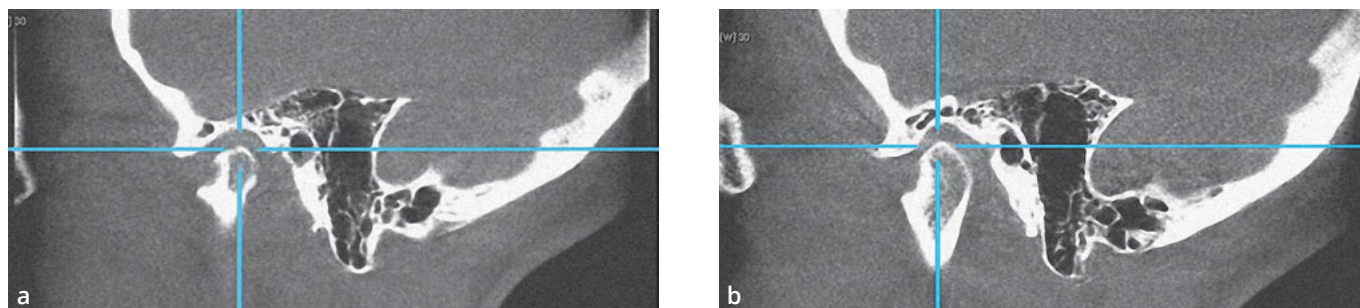


Fig 18a and b Physiologically adjusted condylar positions with inserted COPA.



Fig 19a to c At the end of the orthodontic treatment, the canines are in Class I and take the lead in dynamic occlusion. The physiological anatomy of some molars is lacking, which will be treated later restoratively.

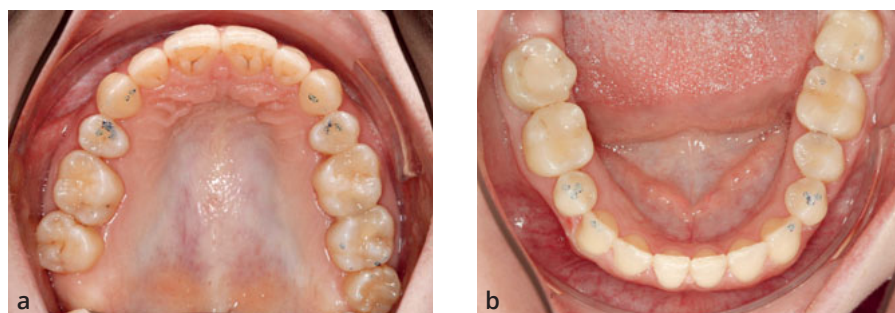


Fig 20a and b The dental arches are well aligned. The incisors have no contact points, the anterior is 'shimstock open'.

The orthodontic treatment was performed in the same way as previously demonstrated (see Fig 23).

At the end of treatment, the arches were aligned, the premolars and molars were in contact, there was canine guidance and the incisors were 'shimstock open' during HIP (Figs 19 and 20). Aesthetics were improved simultaneously

(Fig 21). The CBCT at the end of the orthodontic treatment shows the position of the condyles in the same position as they were adjusted with the occlusal splint (Figs 22 to 24). This demonstrates that the condyle position found with the COPA was converted by means of orthodontic treatment.

Fig 21a and b The function as well as the aesthetics are improved. Before treatment, there were (a) black lip corridors that were filled after the orthodontic treatment by the posterior transversal expansion (b).

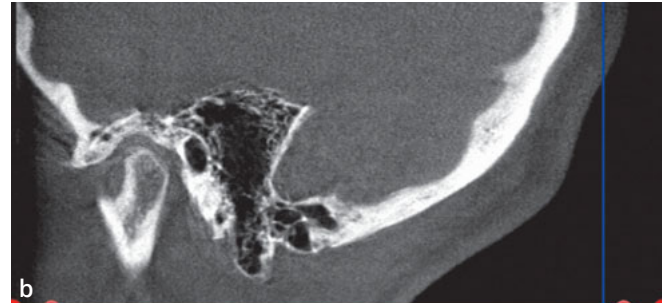
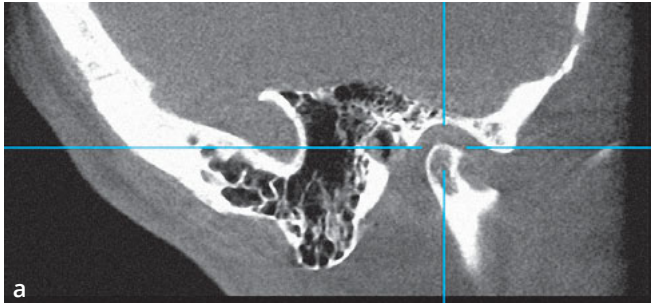


Fig 22 The CBCT images of (a) the right temporomandibular joint and (b) the left temporomandibular joint, after orthodontic treatment showing physiological positioning, as set before the orthodontic treatment by COPA.



Fig 23a to f Course of treatment. (a and b) Situation before orthodontic treatment with COPA onlays. (c and d) Situation after the first phase of Invisalign treatment. (e and f) Situation after orthodontic treatment.

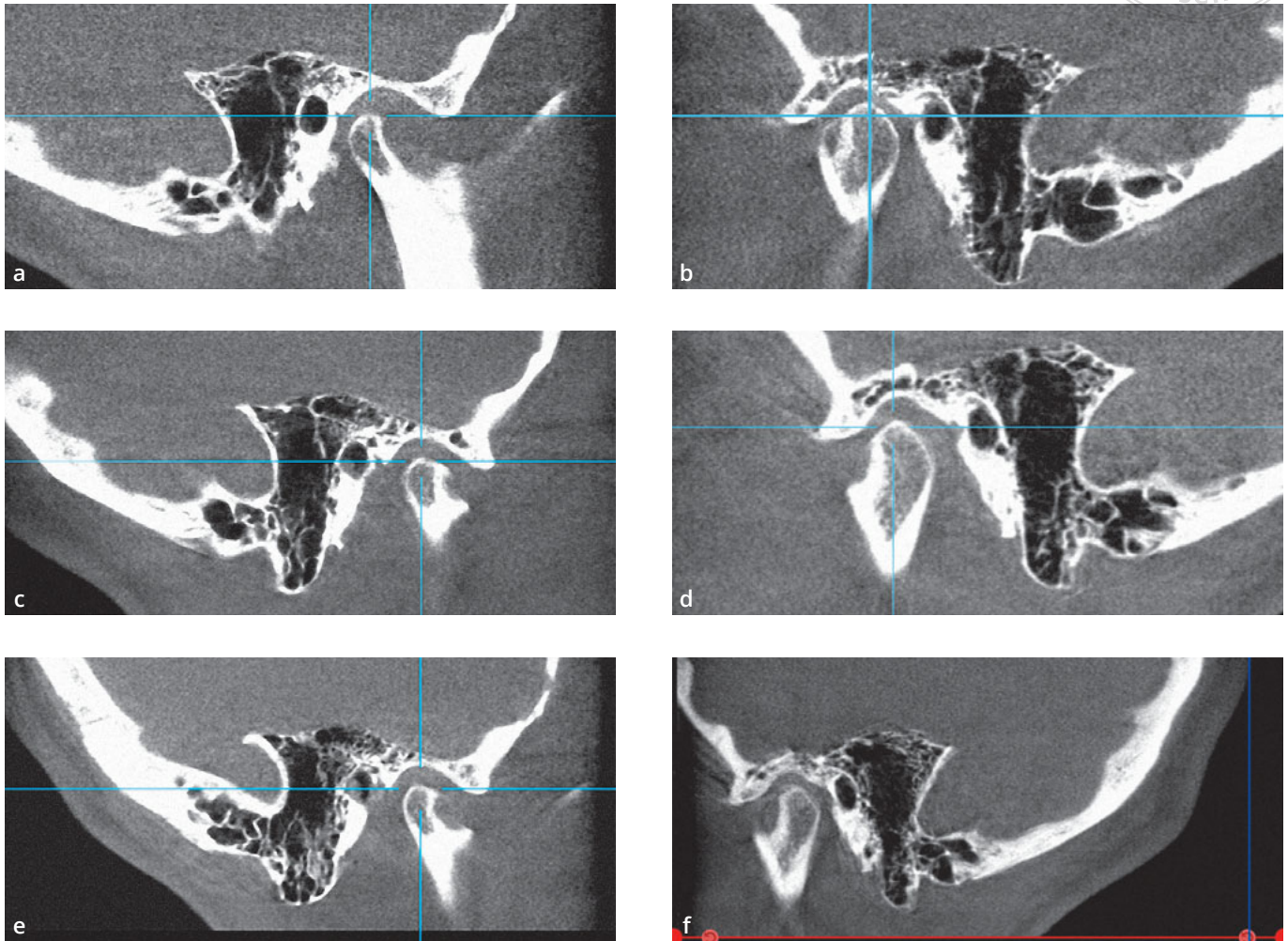


Fig 24a to f Comparison of CBCT scans during the course of treatment. **(a and b)** CBCT scans of the right and left temporomandibular joints before treatment. **(c and d)** CBCT scans of the right and left temporomandibular joints with removable COPA in situ. **(e and f)** CBCT scans of the right and left temporomandibular joints after orthodontic treatment with Invisalign technique combined with COPA onlays.

Restorative therapy

The aim of restorative final treatment is to achieve a stable interdigitation by targeted reconstruction of occlusal surfaces, in which all posterior teeth simultaneously and uniformly come into contact with axially directed forces, while the anterior teeth do not occlude at all or only minimally. In dynamic occlusion, the posterior teeth should disclude interference-free. Due to the orthodontic treatment, the final necessary restorative measures were limited to the reconstruction of the physiological chewing anatomy of individual teeth, to optimise the antagonistic contacts, while maintaining the vertical dimension achieved (Fig 25).

For example, the mandibular right first molar and left second premolar and first and second molars (teeth 46, 35, 36 and 37) were planned to be reconstructed with adhesive CAD/CAM-milled full-zirconia onlays, replacing the existing, insufficient fillings (Fig 26). For the endodontically treated mandibular right second molar (tooth 47), a crown was provided. Analogous to the orthodontic procedure, the therapeutically obtained mandible position, i.e. the position in which the patient is symptom-free, was transferred 1:1 to the definitive restoration (Fig 27). Both aesthetics and occlusion remained stable after 5.5 years of treatment (Fig 28).

Fig 25a and b The casts mounted in the mean value articulator (SAM Dental, Gauting, Germany) show the contact point distribution (blue) and the guidance in dynamic occlusion (red).

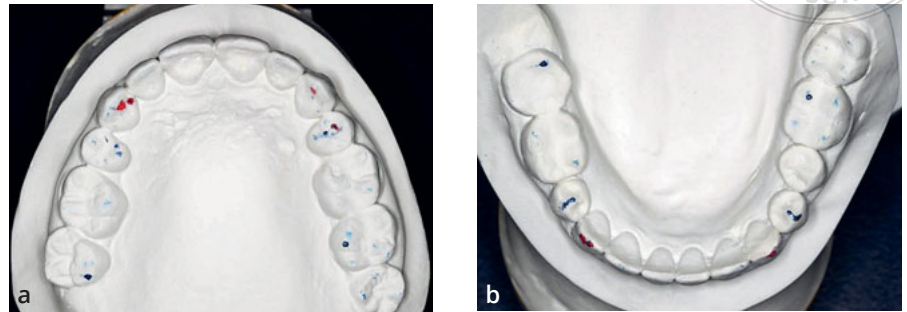


Fig 26a to c Milled restorations made of Prettau zirconia (Zirkonzahn, Gais, Italy).



Fig 27a to f Orthodontic-prosthetic treatment with functional support zones and simultaneous contact of all posterior teeth (**a** and **c**) in static occlusion [black marks (**d** and **e**)]. The dynamic occlusion is guided interference-free over the anterior teeth [laterotrusion, red markings; protrusion, blue markings (**d** and **e**)]. (**b** and **f**) Aesthetic result in the anterior view.

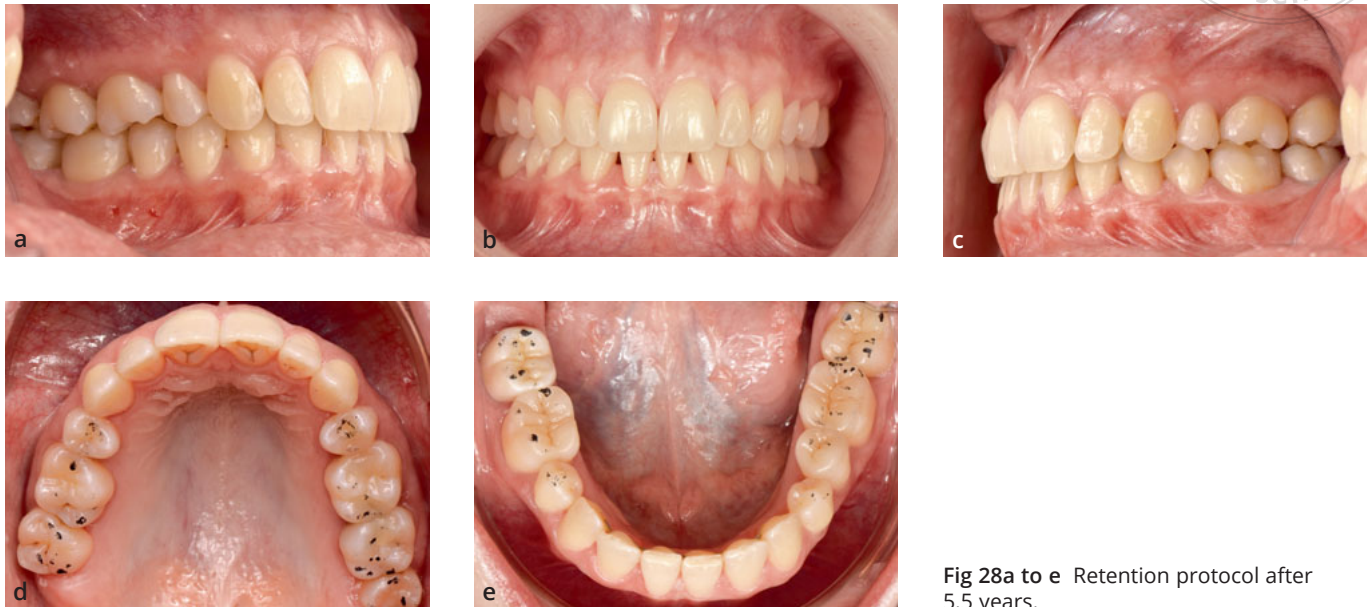


Fig 28a to e Retention protocol after 5.5 years.

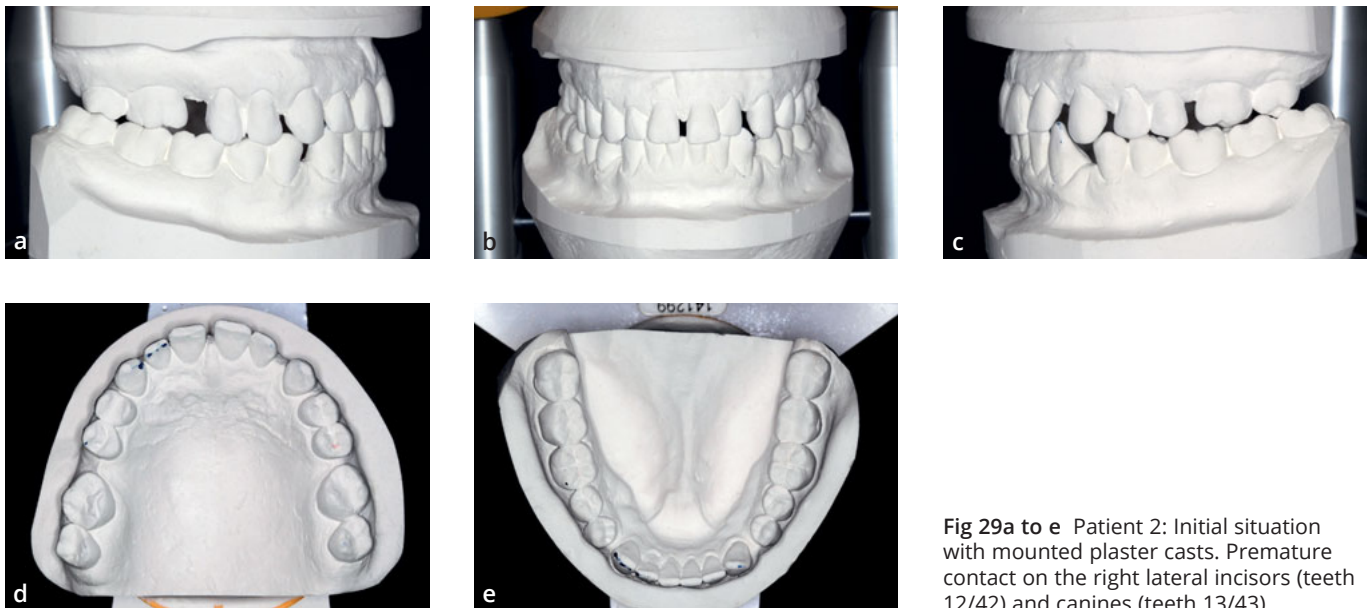


Fig 29a to e Patient 2: Initial situation with mounted plaster casts. Premature contact on the right lateral incisors (teeth 12/42) and canines (teeth 13/43).

Patient 2

A 60-year-old man with good general health status complained of TMJ pain, on the right more than left. He also suffered from lower back pain frequently. Dental treatment of the TMJ had not previously taken place.

Diagnostics

Clinical examination revealed palpation pain of the TMJs significantly more on the right than the left. This correlated with the CBCT of the right TMJ, which showed a significantly reduced joint space in the cranial-posterior dimension (see Figs 30 and 31). The mounting of the initial casts in the articulator showed occlusal contact points in centric relation only on the maxillary right lateral incisor and canine (teeth

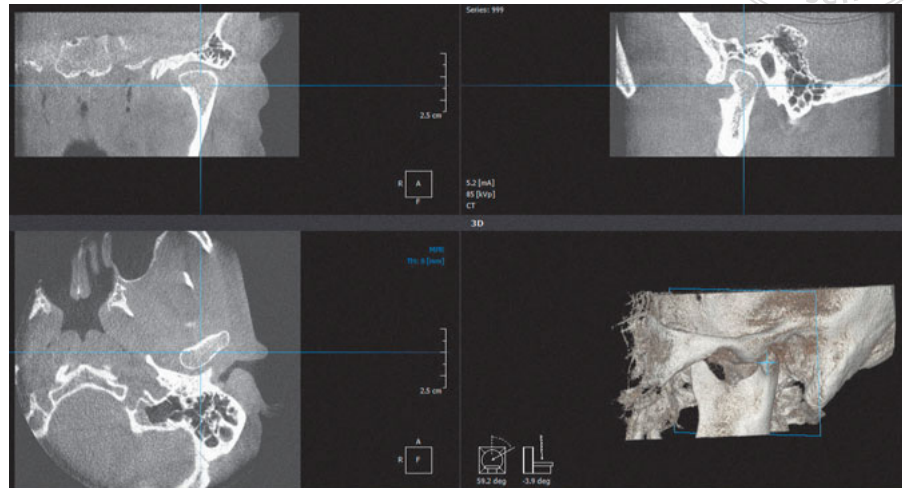


Fig 30 Initial CBCT in habitual intercuspation, left.

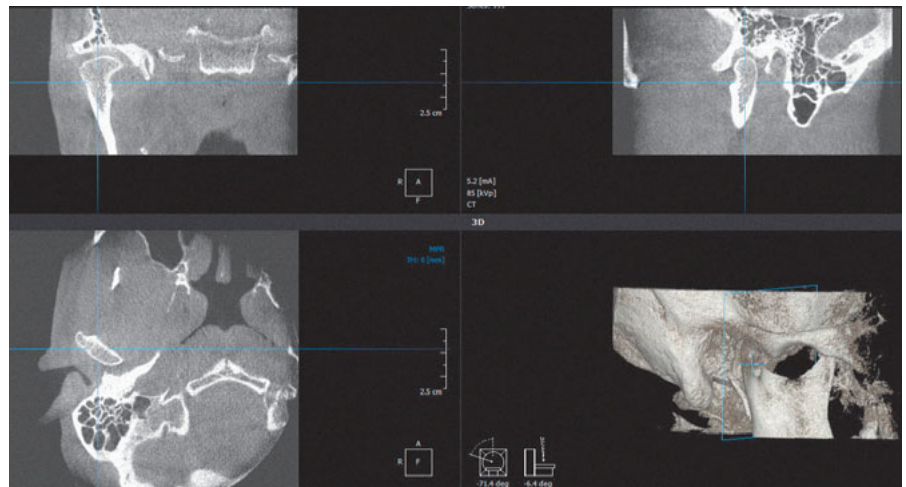


Fig 31 Initial CBCT in habitual intercuspation, right.



Fig 32a to d COPA onlays on mandibular left first molar, second molar (teeth 36 and 37) and right first molar and second molar (teeth 46 and 47) in centric relation.



Fig 33a and b Directly bonded attachment (DBA), direct modulation and finished preparation was followed by intraoral scanning. This procedure is accepted by the manufacturer and results in more precise aligner fitting on the attachments.



Fig 34a to e Start of Airnivol treatment with directly bonded attachment (DBA) and COPA onlays.

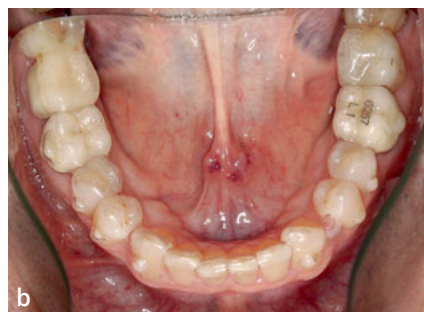


Fig 35a and b Airnivol aligner 1 in situ.

12 and 13), and thus there was a lack of vertical support in the posterior region (Fig 29).

Orthodontic treatment

Due to the necessity for orthodontic treatment, this patient was directly treated with the combination of COPA onlays and aligner orthodontics. The onlays were produced in the articulator (Fig 32). The laboratory-made onlays were bonded to the molars with Maximum Cure (Reliance Ortho-

dontics, Itasca, IL, USA) as previously described. The attachments were bonded directly to the enamel before scanning (Fig 33). After airborne particle-abrasion, the enamel was etched for 5 to 10 seconds. Optibond FL (Kerr Dental, Bioggio, Switzerland) was used as bonding agent. For the direct modulation of the attachments Enamel Plus HFO (GDF, Rosbach, Germany) was used. In the scan, the attachments appear with the same precision as the enamel and therefore the final fitting of the aligners was just as precise on the

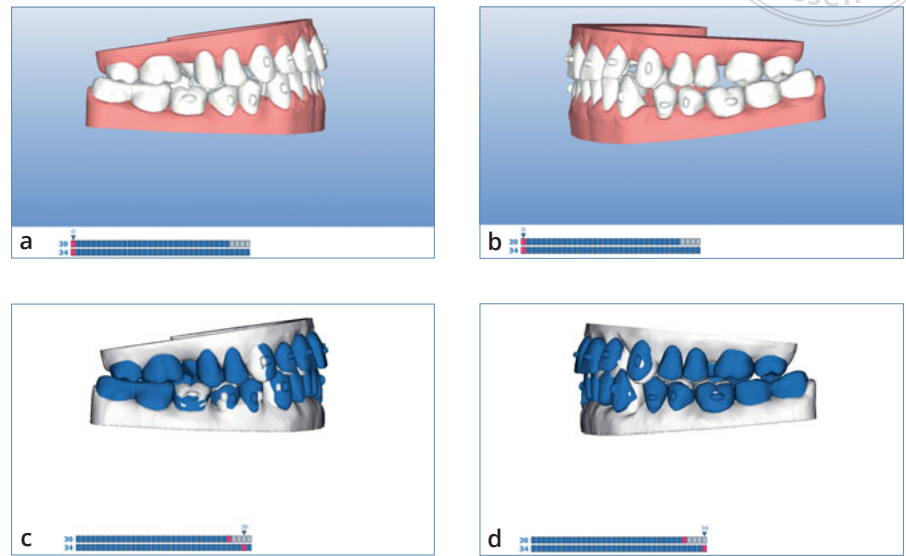


Fig 36a to d First confirmed 'Aircheck' showing (a and b) the initial situation and (c and d) superimposition at the end of the first treatment phase.

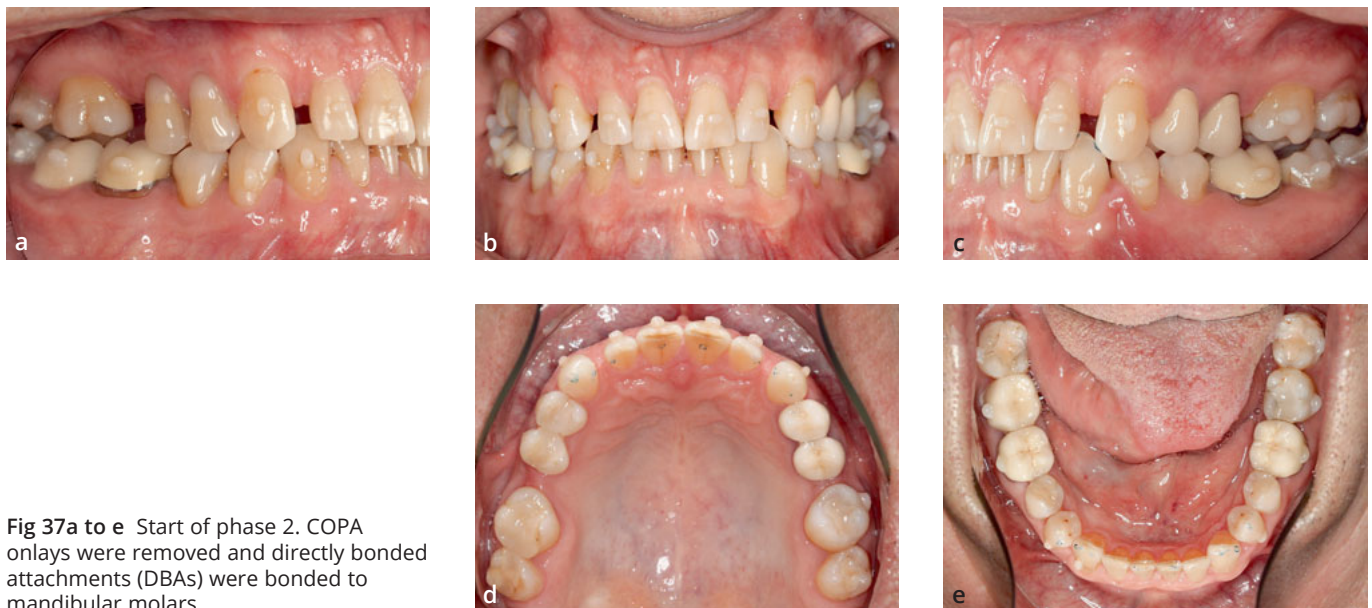


Fig 37a to e Start of phase 2. COPA onlays were removed and directly bonded attachments (DBAs) were bonded to mandibular molars.

attachments as on the enamel. Aligner treatment was performed with Airnivol (Nivol, Pisa, Italy). The orthodontic treatment procedure is depicted in Figs 34 to 38.

Treatment results

At the end of the aligner treatment, the plaster casts showed occlusal contact points on all molars and premolars and a shimstock open incisor area in centric relation (see Fig 40). The posterior vertical support corresponded to the same

posterior vertical support that the patient was given by fixed occlusal splints. Figures 39 and 40 show the final situation before restorative dentistry and aesthetic composite build-up on distal aspects of the maxillary lateral incisors (teeth 12 and 22). The comparison of CBCTs before and after treatment (Figs 41 and 42) shows the significantly improved joint space situation. At the beginning of the treatment a particularly compressed maxillary vertical joint space (0.5 mm) was diagnosed. At the end of treatment,

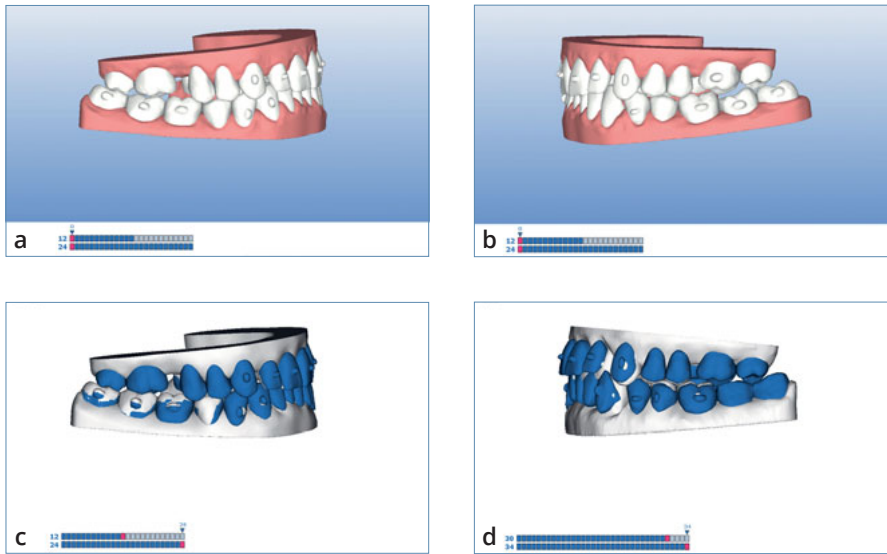


Fig 38a to d Second 'Aircheck' showing (a and b) situation with removed onlays and (c and d) superimposition at the end of treatment.



Fig 39a to e Final intraoral situation before restorative dentistry and reconstruction of maxillary lateral incisors (teeth 12 and 22).

joint space had increased to 2.8 mm. The patient was pain-free.

Discussion

TMD is often associated with a dysfunction of the musculo-skeletal system with multifactorial aetiology. The occlusion plays a superior role in this context as it guides the TMJs during final jaw closure. Therefore, a short screening test

should be carried out by the practitioner at all times and for every patient before the orthodontic treatment starts¹¹. If this short screening delivers positive findings, a detailed diagnosis of the temporomandibular system and musculo-skeletal system takes place^{12,13}, and a reversible therapy by means of a COPA is indicated¹⁴.

If the splint therapy is successful, an orthodontic correction of the occlusion in the physiological mandibular condyle position formerly defined by the COPA should follow. Aligner orthodontics is an ideal tool for this type of treat-

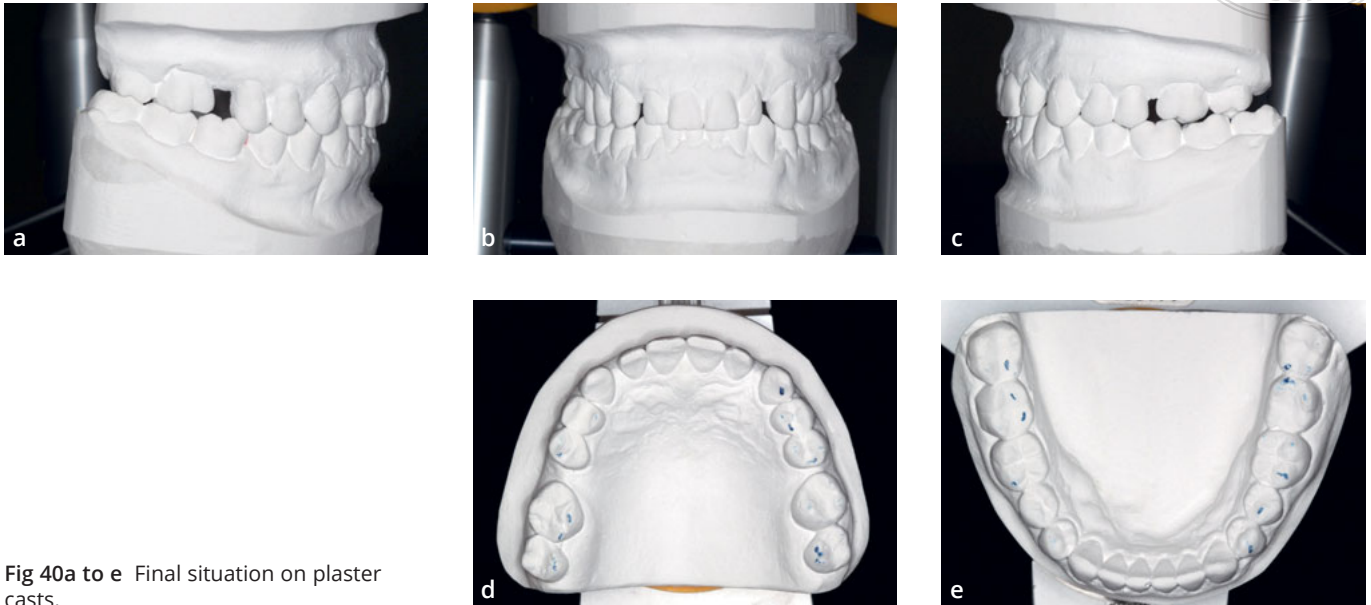


Fig 40a to e Final situation on plaster casts.

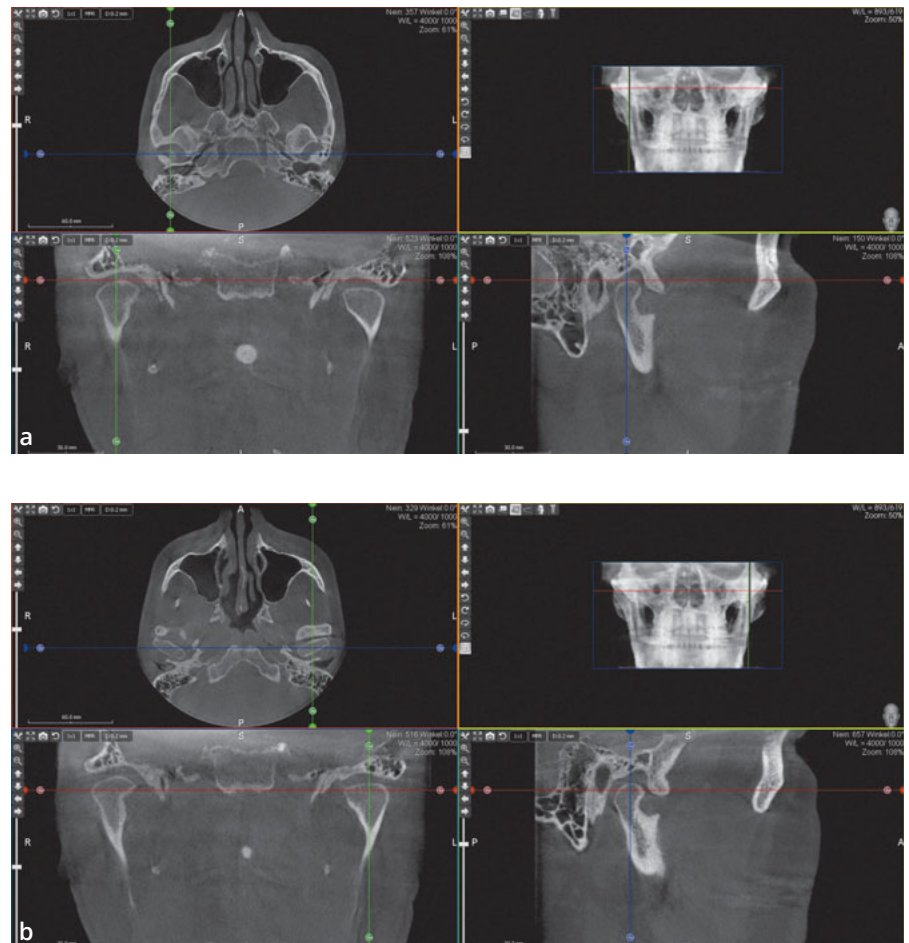


Fig 41a and b Final CBCT (a) right and (b) left.

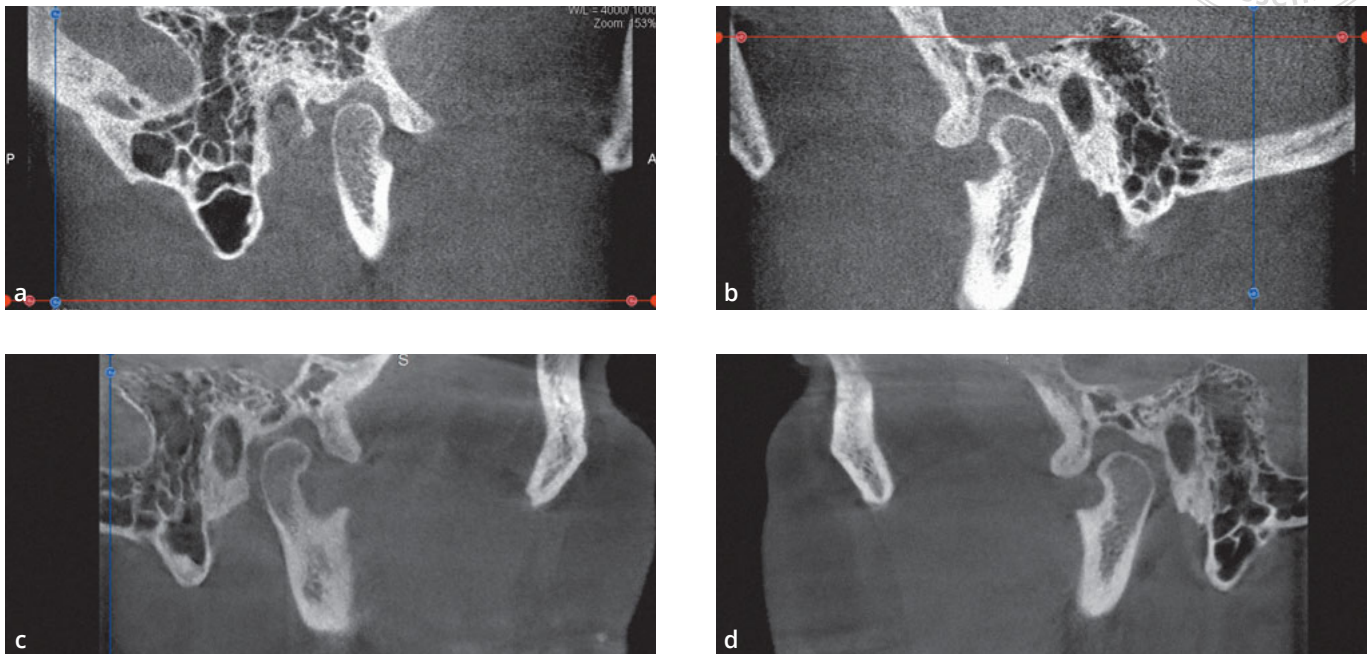


Fig 42a to d Comparison of condyle positions (right and left) in the CBCT before (a and b) and after (c and d) treatment.

ment¹⁴⁻¹⁶ as teeth that stabilise the condyle position will not be moved.

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