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Orthodontics at the crossroads: A closer look at occlusion, temporomandibular disorders and the role of cutting-edge technology

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ABSTRACT

The field of orthodontics strives to achieve an aesthetic, healthy, and stable occlusion. However, traditional practices often assess occlusion in maximum intercuspidation without adequately considering the biomechanics of the temporomandibular joint (TMJ), which can lead to overlooking critical occlusal factors. This perspective paper revisits the debate on the role of occlusion in temporomandibular disorders (TMD) and evaluates the efficacy of current treatment approaches, emphasizing the limitations of conventional methods and the lack of evidence supporting joint-oriented orthodontics. By integrating jaw tracking systems and digital workflows, a comprehensive evaluation of dynamic and static occlusion with realistic mandibular movement allows for a more individualized treatment approach to ensure optimal treatment outcomes.

Introduction

The field of orthodontics presents a formidable challenge in the diagnosis and treatment of achieving a harmonious, esthetic, healthy, and stable occlusion. Conventionally, in orthodontics, dental models are not mounted in articulators, and occlusion is assessed in maximum intercuspidation (MI). This approach often neglects the biomechanics of the temporomandibular joint. Due to the current state of evidence and the absence of evidence supporting joint-oriented orthodontics, the widely accepted method of diagnosis is to assess patients in their maximum intercuspidation position. It can be contended that achieving the six keys of normal occlusion, as proposed by Lawrence Andrews should be the sole objective of orthodontic care[1], and that dynamic occlusion and static occlusion in relation to a physiologic condylar position can be neglected.

Influence of occlusion on the stomatognathic system

Occlusion and TMD

It should be recognized that occlusal factors have been identified as contributing to the development of temporomandibular disorders (TMD).[2] While some research suggests that occlusal factors should not be considered as a primary cause or co-factor, they are still regarded as a risk factor for TMD.[3] Walton and Layton state that the role of naturally occurring mediotrusive interferences with regard to TMD remains unclear.[4] Manfredini et al. suggest that the presence of an MI/CR slide and functional interferences can be better explained by pain adaptation.[5]

A comprehensive review by Cordray reveals a connection between condylar displacement from MI to CR and TMD, which eventually is guided by the occlusion.[6] Assessment of an MI/CR slide would necessitate joint-oriented articulation of the dental models.[7] The research conducted by Manfredini et al. and Cordray highlights the ongoing debate surrounding the role of dental occlusion and its potential impact on TMD.[5,6] With respect to the relationship between malocclusion and TMD, there have been conflicting findings regarding posterior crossbite, anterior open bite, class III, and excessive maxillary overjet. Some studies have reported an association between these factors and TMD, while others have not found a correlation.[8-10] As a result, the issue remains controversial.

Occlusion and tooth structure

It should be noted that the influence of premature contacts is not limited to TMD but is also strongly associated with the development of noncarious cervical lesions (NCCL), suggesting that non-axial occlusal forces

Abbreviations: MI, maximum intercuspidation; TMD, temporomandibular disorders; CBT, cognitive behavioral therapy; CR, centric relation; CT, counseling therapy; NCCL, non-carious cervical lesions; JTS, jaw tracking systems

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Fig. 1. Non-carious cervical lesions, wear facets, class II malocclusion with anterior crowding − right lateral intraoral situation

and eccentric contacts can result in tooth flexure and strain in the cervical region (Fig. 1).[11,12] A significant correlation has also been found by Collio et al. for the prevalence of abfractions in subjects with a discrepancy in MI and centric relation (CR).[13]

Occlusion and periodontal health

Research conducted by Rios et al. demonstrated a strong correlation between occlusal conditions and periodontitis.[14] It is essential to recognize that occlusal interferences can exacerbate periodontal compromised situations, leading to pathologic tooth migration.[15] It has been described that mediotrusive interferences should be avoided in therapeutic concepts to prevent pulpal and periodontal complications, as well as structural and mechanical issues.[4]

According to a rat model, it was demonstrated that following orthodontic tooth movement, the emergence of occlusal interferences or insufficient contacts resulted in increased inflammation of the periodontal tissue and bone resorption. Furthermore, it was determined that these occurrences were linked to a higher likelihood of relapse. Consequently, it was recommended that occlusal adjustments should be carried out subsequent to active orthodontic treatment.[16]

The findings emphasize that occlusal factors have an impact on various aspects of the stomatognathic system, which underscores the necessity of integrating comprehensive treatment planning approaches considering not only esthetics but also function.

Critical review of current literature on temporomandibular disorders

There are multiple treatment options available for TMD, including cognitive behavioral therapy (CBT), physiotherapy, splint therapy, occlusal equilibration, surgical procedures, pharmacotherapy, and combined treatment.[17]

The British Medical Journal has issued a recent guideline that suggests CBT and mobilization techniques as more suitable treatment options for individuals with chronic TMD, rather than splint therapy.[18] The guideline[18] specifically refers to a systematic review[19] showing low evidence and inefficiency of oral splints in reducing pain when compared to no or minimal treatment.

A critical examination of the systematic review reveals that the findings are not surprising and that some concerns should be raised. The studies included in the review were highly heterogeneous, and when pooled together, they do not allow for a general conclusion about the efficacy of occlusal splints. The duration of follow-up and active study time varied greatly, ranging from two weeks[20] to 12 months[21], and even the splint design was highly variable, ranging from jig appliances[20,22], vacuum-formed splints[23], Michigan splints[20,24] to flat occlusal splints[25]. Not all studies provided a generalized statement regarding the presence or absence of anterior and canine guidance without interference during excursive movements, leaving room for interpretation regarding the occlusal and functional concept.[21,26] Additionally, most of the studies showed that splints had occlusal contacts, but this does not necessarily mean that the surface was always smooth and flat, which is beneficial in myopathies to allow for muscular repositioning of the mandible. The majority of the studies failed to provide details on the adjustments of splints, as well as overlooked the significance of the clinician's expertise.[20,25,27,28] All studies had the commonality that the splints were usually worn at night, with some studies recommending additional daytime wear mostly of one or two hours.[21,23,27,28] Considering the stated wear time and an average global sleep duration of seven hours[29], it can be assumed that in most cases the splints were only worn for about seven to nine hours. In contrast the authors' perspective on optimal wear time of splints is approximately 22 hours per day, especially in adult populations, as the prevalence of awake bruxism in adults and the amount of occlusal contact time during the day are higher[30,31], leading to constant stimulation of periodontal mechanoreceptors that play a role in neuromuscular pathways.[32] Therefore the efficacy of splints worn at night might not be entirely effective, particularly in adults, although children may be an exception due to their higher prevalence of sleep bruxism.[30]

The variability in design, follow-up duration, and lack of standardized occlusal adjustment protocols challenge the generalizability of findings, underscoring the need for a more nuanced understanding of splint therapy's role in TMD management.

In a network meta-analysis conducted by Al-Moraissi et al., a substantial reduction in post-treatment pain intensity was demonstrated through the use of hard stabilization splints.[33] The use of additional counseling therapy (CT) has been found to result in a minor level of increased pain reduction.[33] It is essential to acknowledge the impact of CBT and CT, as these are effective modalities in addressing pain-related issues.[34,35] According to a systematic review conducted by Liu et al., the literature provided insufficient evidence regarding CBT. The studies contained within the literature showed high heterogeneity, substantial differences in follow-up periods, and controls, which led the authors to decline performing a meta-analysis.[36]

Our standard protocol for treating temporomandibular disorders with muscular origin, with a possible causality related to altered joint function[37], typically involves the use of oral splint therapy, which features a height depending on a 2mm disclusion of the posterior molars. The splint is designed with anterior and canine guidance, and its surface is smooth and flat, featuring one centric contact at each premolar and molar and no centric contacts in the frontal area (Fig. 2). Patients are required to wear the splint for at least 22 hours per day, and occlusal adjustments are made according to the described pattern on a weekly basis until the occlusal contacts remain stable. This approach differs from the aforementioned literature. It is crucial to mention that the TMD therapy is an entity on its own but often followed by a subsequent orthodontic treatment as alterations of the occlusion can be caused by the TMD therapy (Fig. 3).

The joint-oriented treatment workflow in digital orthodontics

A main principle is at first instance not to cause any harm − "primum nihil nocere". The question that presents itself is which course of action inflicts more harm: neglecting to address a risk factor for pathology or even creating risk factors or adhering to established principles and providing anterior and canine guidance to prevent interfering contacts? The authors' perspective on the matter is clear as occlusal interferences also contribute significantly to the formation of various other conditions.

To prevent negative consequences from premature contacts, the orthodontic models should at least be mounted with a CR record prior the removal of orthodontic appliances to aim for a mutually protected occlusion. Ideally, treatment should also be initiated in this manner.

Traditionally this was accomplished by utilizing plaster models, CR registration and determination of the hinge axis either arbitrarily or conventionally to mount the models into an articulator. The incorporation

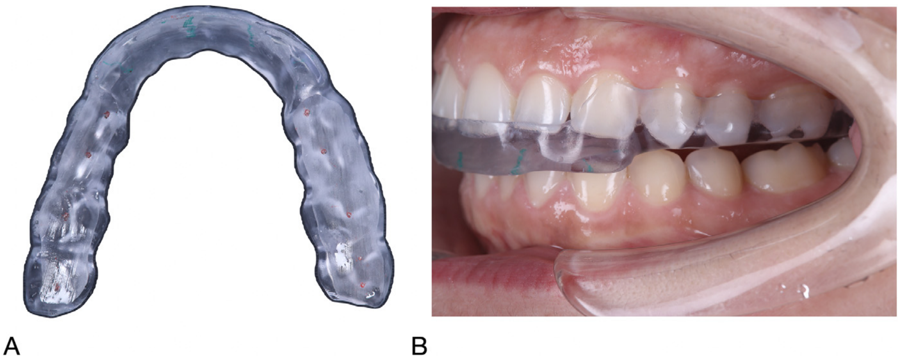

Fig. 2. A – Occlusal view of a splint with flat posterior surfaces with single static contacts for each tooth (red) and anterior and canine guidance (green); B- intraoral left lateral view of inserted splint

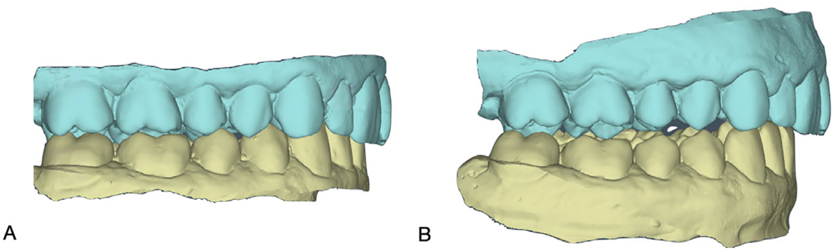

Fig. 3. A – sagittal occlusal relationship prior to splint therapy, B – sagittal occlusal relationship after splint therapy

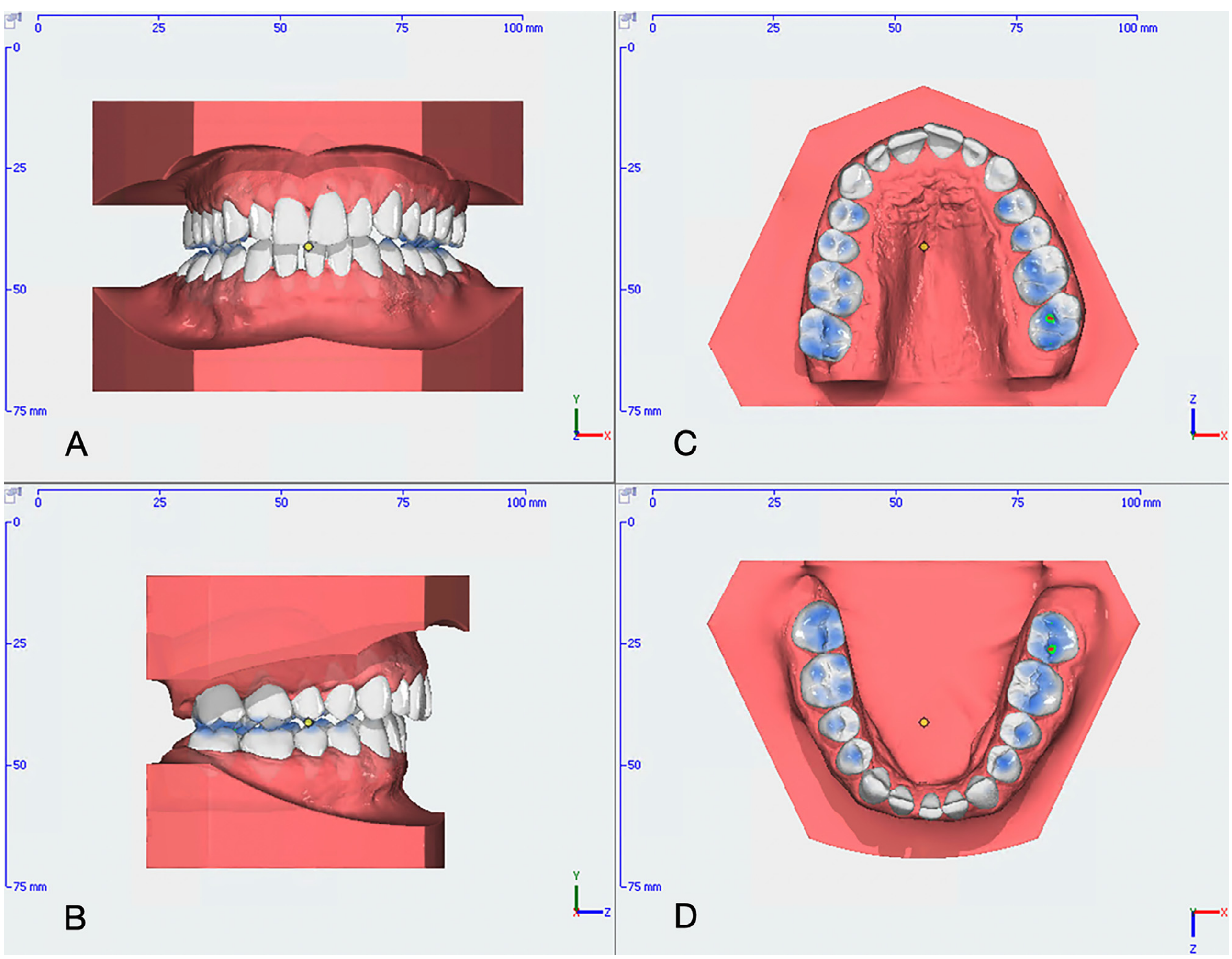

Fig. 4. Scanned articulated plaster casts in CR imported to OnyxCeph (Image Instruments GmbH, Chemnitz, Germany); A – frontal view, B – lateral view, C- upper jaw occlusal view with contact points, D – lower jaw occlusal view with contact points

Fig. 5. Visualization of the calculated hinge axis and the arbitrary axis – Twim Software (Modjaw, Villeurbanne, France)

of intraoral scanners in orthodontics has led to the potential benefits of a full digital workflow. Historically, the joint-oriented full digital workflow in orthodontics was more than challenging. One innovative approach for treatment diagnosis and dynamic evaluation of mandibular movements in real time required the utilization of cone-beam computed tomography which resulted in additional radiation exposure.[38] Furthermore, the available system at that time (Sicat, Bonn, Germany)[39] did not allow to perform orthodontic setups and could therefore only be used as diagnostic tool. Alternatively mounted plaster models had to be scanned in a modelscanner capable of scanning with articulators (e.g. Zirkonzahn GmbH S600 Arti, Gais, Italy) with the obtained digital models at CR to be imported into an orthodontic treatment planning software (Fig. 4).

Utilization of jaw tracking systems (JTS) like Modjaw (Modjaw, Villeurbanne, France) or DMD (Ignident GmbH, Ludwigshafen, Germany) aid in providing a reconstruction of individual patient movement and thereby a more realistic treatment approach[40], with accurate information of the intermaxillary relationship[41], and also allow the full digital workflow for joint-oriented treatment modalities in dentistry.

The technology employed in JTS varies, with magnetometry, ultrasound, photometry, and infrared optical systems being the primary options currently available.[42]

The Modjaw device is based on photometrics and is designed to be used with a headband that includes four markers. The concept of the jaw tracking system using markers originates from the field of animation film, where human subjects were outfitted with markers and their movements were recorded. The motions were used to animate characters in films.

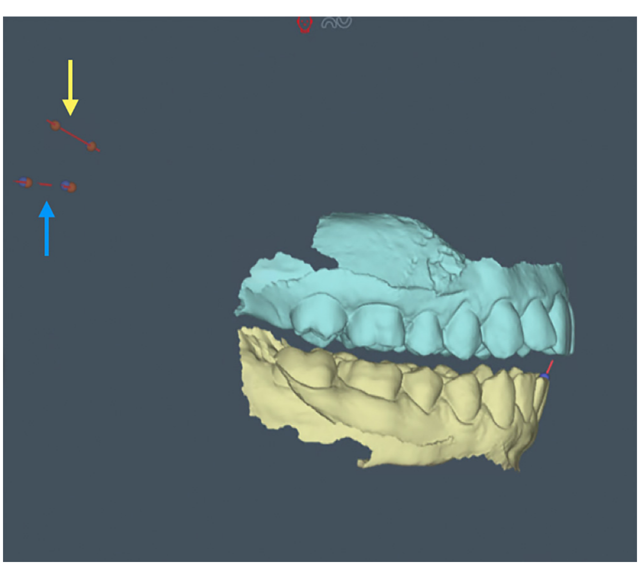

Fig. 6. Intraoral model scans with relationship of pre- and post calculated axis. The blue arrow shows the arbitrary hinge axis and the yellow arrow shows the new calculated hinge axis – Twim Software (Modjaw, Villeurbanne, France)

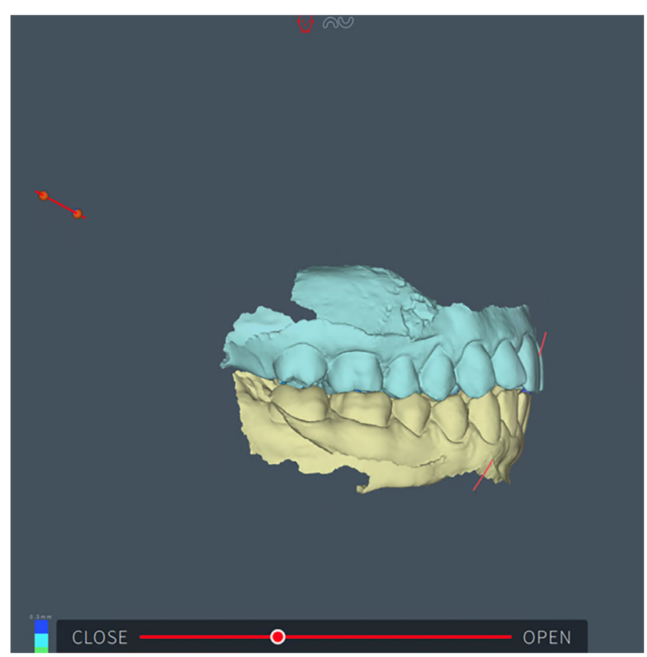

Fig. 7. Rotation around the true hinge axis into first contact position referred as centric relation – Twim Software (Modjaw, Villeurbanne, France)

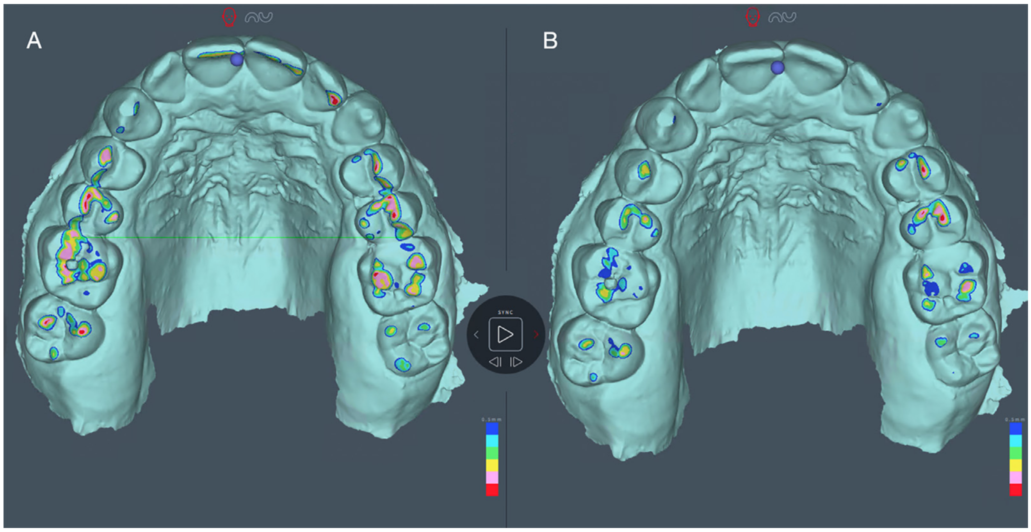

Fig. 8. Changes in occlusal contact points, A: maximum intercuspidation MI, B: centric relation CR − Twim Software (Modjaw, Villeurbanne, France)

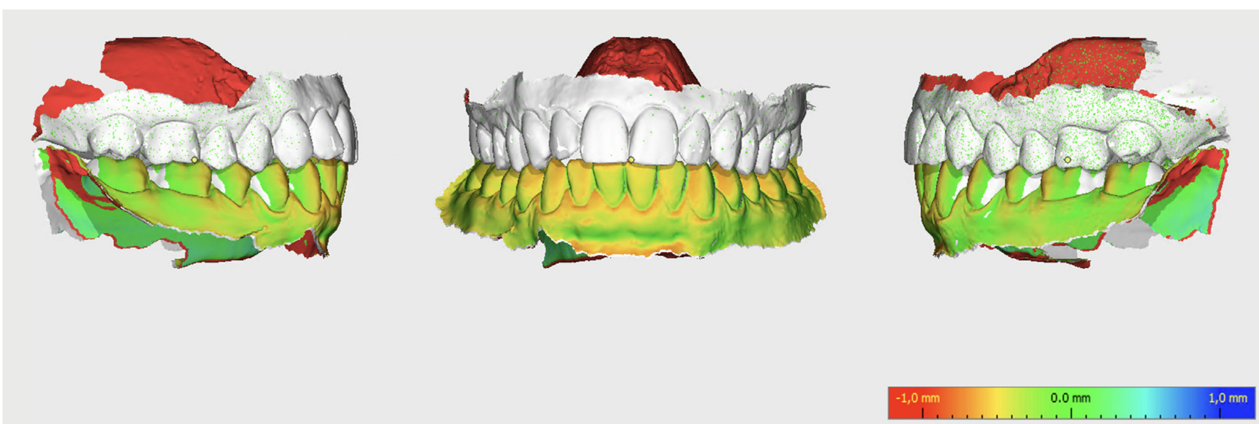

Fig. 9. Superimposition on upper jaw and color coded heat map for lower jaw changes from maximum intercuspidation MI to centric relation CR; A − right lateral view, B − frontal view, C − left lateral view

The system also includes a paraocclusal bitefork, which is positioned at the lower teeth using self-curing composite for provisional crowns and bridges (Structur 3, VOCO GmbH, Cuxhaven, Germany). It is important to ensure that no composite is in contact with the opposing teeth during maximum intercuspidation or excursive movements. Another holder with markers is attached to the bite fork, and the stereocamera is adjusted based on the distance and height. To record dynamic movements, the system is calibrated by providing reference points for the arbitrary hinge axis and subnasale and for four occlusal points in the lower dentition.

The true hinge axis is calculated by asking the patient to open and close their mouth by 5-10mm a few times, while instructing them not to touch their teeth during closure to minimize the influence of neuromuscular engrams.[43] Alternatively, the clinician can guide this movement.

As the rotational condylar movement is recognized by the software, the true hinge axis can be determined, and the models will be oriented accordingly (Figs. 5, 6). Then, the clinician will actively rotate the lower jaw to the first contact positions, which will be referred to as the CR position (Fig. 7). The mandibular position in CR and MI is different, and this can be visualized by showing changes in occlusal contacts (Fig. 8) and by exporting the CR models into the orthodontic treatment software with superimpositions on the upper jaw, displaying the difference in jaw position in color-coded heat maps (Fig. 9).

After tooth segmentation and virtual model preparation, the imported hinge axis can be visualized, and the jaw can be rotated around it during treatment planning for precise joint-oriented orthodontics (Fig. 10). The CR position is now the starting point of orthodontic treatment, and the teeth should be aligned accordingly. The protocol described is the minimal protocol needed for joint-oriented orthodontics. In the finishing phase, the protocol should be extended to include dynamic protrusive and laterotrusive movements, as well as mouth opening and closure, to check for interferences and finish the case accordingly.

The importance of achieving a functional occlusion without interference cannot be overstated, as it is essential for optimal treatment outcomes. It is possible that occlusal adjustments or restorations may be necessary to ensure a successful outcome (Fig. 11).

Conclusion

The integration of digital technological advancements like jaw tracking systems in orthodontics enables a comprehensive digital treatment workflow and an accurate evaluation of dynamic and static occlusion. Research on the influence of occlusal factors suggest that interferences can have a negative effect on the condition of the stomatognathic system. Orthodontic treatment goals should therefore consider joint-

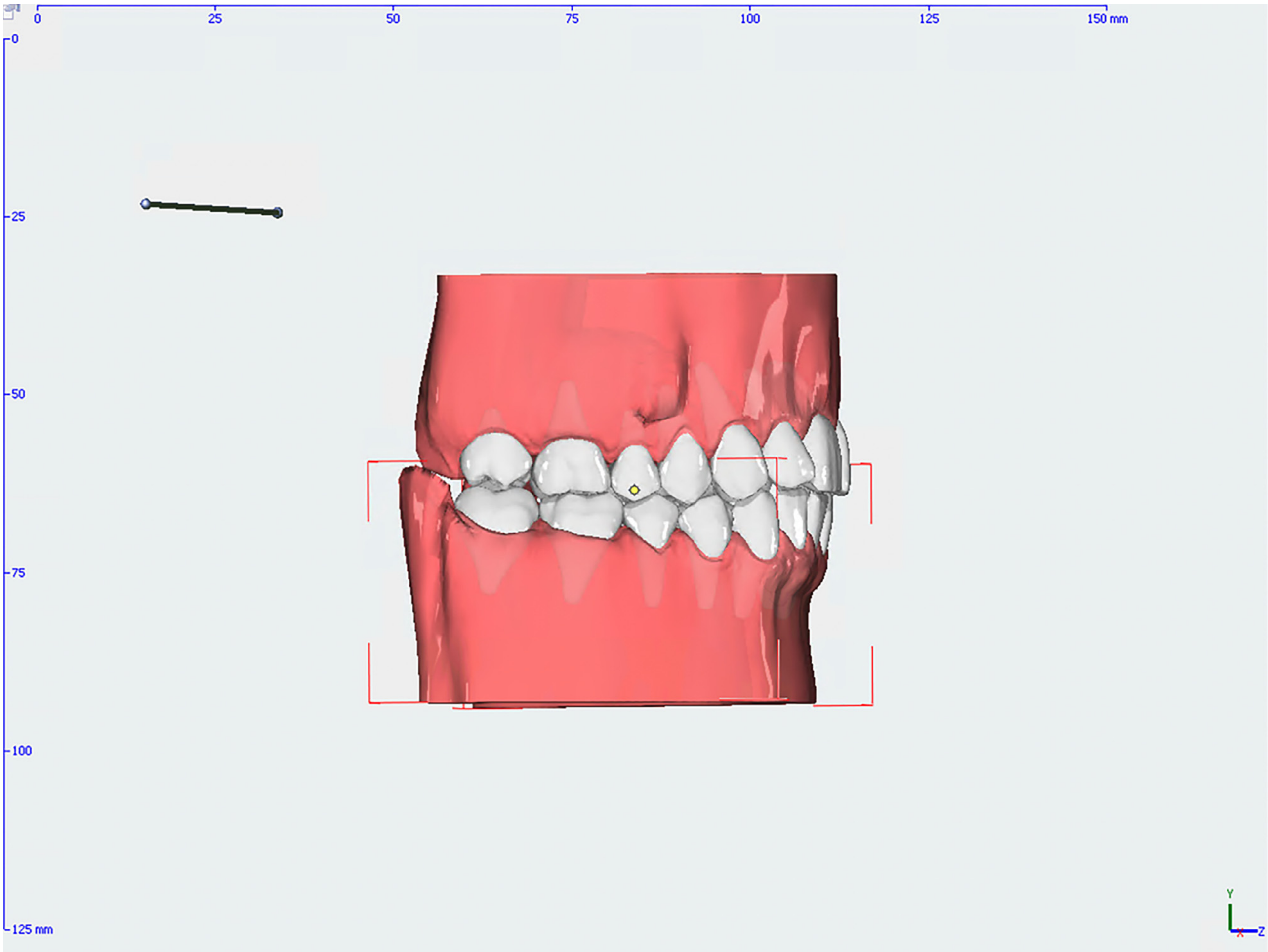

Fig. 10. Segmented models for orthodontic treatment with the true hinge axis in the treatment planning software OnyxCeph (Image Instruments GmbH, Chemnitz, Germany)

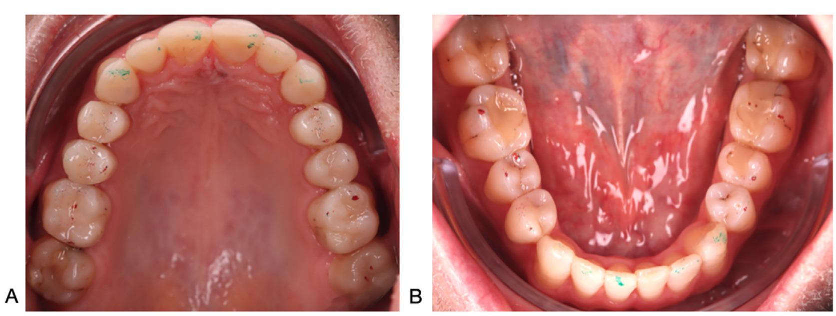

Fig. 11. Occlusal contacts after finishing a case with anterior and canine guidance after orthodontics and occlusal rehabilitation with flowable composite injection method; A − upper jaw occlusal view, B − lower jaw occlusal view

oriented dynamic occlusion and principles of a mutually protected occlusion should not be disregarded.

Consent for publication

Only anonymised patient data was used and no patient data revealing the identity of the patients is published therefore consent of publication can be waived.

Availability of data and materials

All data are available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Sachin Chhatwani: Writing − review & editing, Writing − original draft, Conceptualization. **Vanessa Knode:** Writing − review & editing, Validation, Conceptualization. **Stephan Christian Möhlhenrich:** Writing – review & editing, Validation, Conceptualization. **Werner Schupp:** Writing − review & editing, Validation, Conceptualization. **Gholamreza**

Danesh: Writing – review & editing, Project administration, Conceptualization.

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