How effective are digital approaches in enhancing occlusal accuracy for full-mouth rehabilitations?

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How effective are digital approaches in enhancing occlusal accuracy for full-mouth rehabilitations?

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ABSRACT

How effective are digital approaches in enhancing occlusal accuracy for full-mouth rehabilitations?

Purpose: This review aims to evaluate the effectiveness of digital methods in minimizing occlusal discrepancies in full-mouth rehabilitations. This paper evaluates enhancements in accuracy, reproducibility, and clinical outcomes by contrasting traditional analog methods with digital workflows, which encompass intraoral scanning, digital jaw relation recording, and computer-aided occlusal analysis.

Material and methods: A comprehensive literature search was carried out on PubMed, Scopus, and Sciencedirect for articles published from 2010 to 2025. Out of 310 studies screened, 52 were deemed to meet the inclusion criteria. The studies included those that evaluated digital methods for occlusal registration, compared digital workflows with conventional ones, or examined clinical outcomes regarding occlusal accuracy. Data extraction and thematic synthesis were performed.

Results: Fifty-two studies demonstrate that digital methods enhance occlusal accuracy, reproducibility, and workflow efficiency in full-mouth rehabilitation. Intraoral scanners, digital CR tools, and virtual articulators outperform conventional techniques. CAD/CAM systems improve prosthesis fit and minimize adjustment needs, while T-Scan technology provides measurable occlusal data. Overall, digital workflows yield faster, more precise, and patient-centered outcomes.

Conclusion: Digital occlusal methods offer distinct advantages over conventional techniques, particularly in enhancing precision and efficiency. Emerging technologies such as AI and virtual articulation further improve their clinical impact, although some limitations remain in edentulous applications.

Keywords: digital occlusion, full-mouth rehabilitation, digital approaches, occlusal discrepancies, jaw relation, occlusal accuracy using digital method

I. Introduction

Full-mouth rehabilitation is a comprehensive dental procedure to restore a patient's function, aesthetics, and occlusal stability.(1) Peter E. Dawson defined it as a systematic approach involving a thorough diagnosis, treatment planning, and full-mouth rehabilitation.(2) It addresses various dental issues, including severe tooth wear, missing teeth, malocclusion, temporomandibular joint (TMJ) disorders, and periodontal disease.(3)

The goal extends beyond simply rebuilding and restoring worn dentition; it focuses on ensuring the long-term health and stability of the stomatognathic system.(2, 4, 5) Accurate maxillomandibular relationships and proper occlusal harmony are essential for successful treatment, as discrepancies can result in complications like temporomandibular joint disorders (TMJ), unequal force distribution, restoration issues, and patient discomfort.(5, 6) Although advancements have been made in prosthodontics, conventional methods for occlusal analysis and jaw relation recording still suffer from errors due to manual variability, material distortions, and the limitations of mechanical tools and articulators.(7) These difficulties highlight the necessity for more accurate and dependable methods in full-mouth rehabilitation to improve clinical results and boost patient satisfaction.(5)

1.1. Occlusal Discrepancies in Traditional Methods

One of the primary challenges in full-mouth rehabilitation is the accurate recording of centric relation (CR) and maxillomandibular relationships.(6, 8) Traditional CR registration methods, such as wax records, interocclusal records, and facebow transfer, rely heavily on operator technique and patient cooperation.(9, 10) These techniques are prone to errors due to patient movement, the compressibility of registration materials, and variations in the clinician’s ability to manipulate the mandible into a reproducible CR position.(1, 11)

Articulators, particularly semi-adjustable and fully adjustable models, are frequently used to simulate the movements of the mandible.(8, 12) These devices cannot entirely replicate the dynamic and three-dimensional nature of the temporomandibular joint (TMJ). Consequently, this limitation can lead to occlusal errors and premature contacts when restorations are placed in the mouth.(12) Traditional occlusal analysis methods using static articulation paper or wax lack quantitative data

on force distribution, potentially causing inaccuracies during adjustments due to missing detailed information. (13)

Another significant source of occlusal discrepancies originates from impression materials and fabrication processes. Traditional impression techniques using materials such as polyvinyl siloxane (PVS) and alginate are susceptible to dimensional changes due to shrinkage, expansion, or distortion during polymerization.(14, 15) These flaws can lead to occlusal misalignment once the final prosthesis is seated. Moreover, indirect restorations made using traditional lost-wax casting techniques may experience slight distortions, necessitating intraoral adjustments that could compromise occlusal integrity.(16)

1.2. Advancements in Digital Techniques

With the rise of digital dentistry, new technologies have emerged to overcome the limitations of traditional methods and reduce occlusal discrepancies. Digital workflows, such as intraoral scanning, computer-aided design/computer-aided manufacturing (CAD/CAM), and virtual articulators, have transformed full-mouth rehabilitation by enhancing accuracy and reproducibility.(17) (18, 19)

Digital techniques can eliminate the errors associated with traditional impression materials by capturing accurate digital impressions, free from distortion risks.(20, 21) Incorporating digital methods enhances treatment planning by utilizing the patient's unique features to refine occlusal design, resulting in a more personalized and aesthetically balanced rehabilitation.(22) (23)

Computer-guided occlusal analysis systems provide real-time insights into occlusal force distribution, timing, and balance.(24, 25) Unlike traditional marking papers, these systems measure and quantify occlusal contacts, aiming to identify premature interferences and facilitate more accurate assessment adjustments.(26) (18)

The use of CAD/CAM technology in full-mouth rehabilitation enables the creation of precise restorations, ensuring enhanced marginal integrity and optimal occlusal fit.(20, 25, 27)

1.3. Aim of the Study

This review focuses on the effects of digital workflows in reducing occlusal discrepancies by examining studies related to intraoral scanning, digital occlusal analysis, and computer-guided occlusion adjustments. It also highlights the main benefits of digital workflows over traditional methods in minimizing these discrepancies.

II. Materials and Methods

This review was conducted to evaluate the accuracy, clinical outcomes, and workflow efficiency of digital techniques utilized in occlusal registration for full-mouth rehabilitation. The focus was on comparing digital and conventional methods for CR, occlusal analysis, and prosthetic fabrication, with attention to intraoral scanners, digital articulators, jaw-tracking systems, and CAD/CAM workflows.

2.1. Search Strategy

A structured and comprehensive electronic search was conducted across the following databases: PubMed, and Journal of Prosthetic Dentistry (JPD). Restrictions on PubMed were set on articles in the English language published between 2015 and 2025, freely accessible full texts, and for research articles, clinical studies, clinical trials, reviews, scoping reviews, systematic reviews, and comparative studies. Restrictions for JPD were research and review articles published in the English language between 2015 and 2025 with freely accessible full texts. The following combinations of keywords and Medical Subject Headings (MeSH) terms were used to ensure broad coverage: “digital occlusion, digital occlusal registration, centric relation, use of CAD/CAM, jaw relation recording, digital jaw relation, digital and analog impression, digital impression technique, conventional impression technique, intraoral scanner, occlusal discrepancies, occlusal accuracy using digital method, digital method in occlusal discrepancies, occlusal accuracy, digital workflow in prosthodontics, digital articulator, virtual articulator, digital occlusal analysis, full-mouth rehabilitation, digital full mouth rehabilitation, full-mouth rehabilitation in prosthodontics, digital prosthodontics, digital vs conventional methods”. When searching the databases, the following related entry key words were used in different combinations using the Boolean operators “AND” and “OR”: #1 (“digital occlusion” OR “digital occlusal registration” OR “digital jaw relation” OR “digital articulator” OR “digital occlusal analysis” OR “digital full mouth rehabilitation” OR “digital prosthodontics” OR “digital impression technique) #2 (“centric relation” OR “full mouth rehabilitation” OR “jaw relation recording”) #3 (“virtual articulator” OR “use of CAD/CAM” OR “intraoral scanner” OR “digital vs conventional methods”) #4 (“occlusal discrepancies” OR “occlusal accuracy” OR “conventional impression technique” “digital method in occlusal discrepancies” OR “occlusal accuracy using digital method”).

Additionally, a manual search of reference lists from selected articles was performed to identify further relevant studies.

Inclusion and exclusion Criteria:

Articles were included if they:

- Investigated the clinical application of digital tools for occlusal registration, CR recording, or prosthetic fabrication in full-mouth rehabilitation
- Included clinical studies, pilot studies, technical reports, case series, and literature/systematic reviews
- Provided comparisons of digital and conventional techniques or evaluated independent digital workflows
- Outcomes reported include occlusal accuracy, jaw relation reproducibility, prosthesis fit, workflow efficiency, and patient satisfaction

Exclusion criteria were:

- Non-clinical studies without practical application
- Articles published in languages other than English
- Editorials, commentaries, or conference abstracts
- Articles without accessible full texts or duplicated data

The following questions were raised and discussed in this review:

1. How do digital methods affect occlusal discrepancies in full-mouth rehabilitations?
2. What are the key advantages of digital workflows in reducing occlusal discrepancies compared to conventional techniques?
3. How do intraoral scanners and digital articulation software contribute to better occlusal balance?
4. What are the limitations and challenges of using digital occlusal analysis in clinical practice?

5. What are future developments are needed further to enhance the precision of digital occlusion in full-mouth rehabilitations?

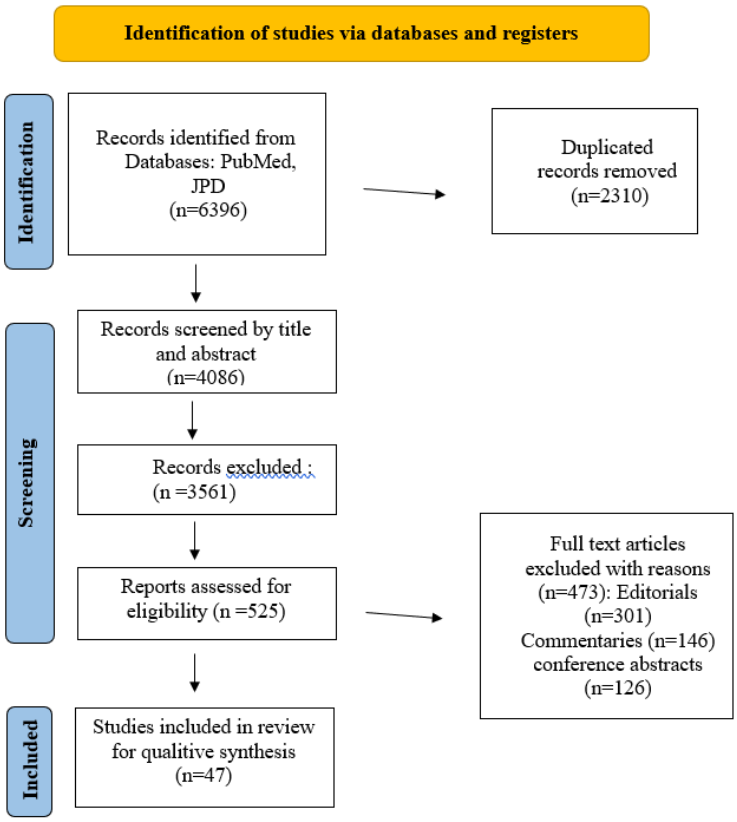

Figure 1. Flow chart for study inclusion

III. Results

A systematic search of PubMed and the Journal of Prosthetic Dentistry (JPD) retrieved a total of 6,396 records (PubMed: 5,067; JPD: 1,329). After removing 2,310 duplicates, 4,086 records were screened based on titles and abstracts. Of these, 3,561 did not meet the inclusion criteria and were excluded. The remaining 525 full-text articles were examined in detail, with 473 excluded because they were editorials (n = 201), commentaries (n = 146), or conference abstracts (n = 126). Ultimately, 47 studies were included in the final qualitative review and organized thematically according to their contributions to digital occlusal workflows in full-mouth rehabilitation.

The literature consistently shows that digital workflows improve the accuracy and reproducibility of occlusal relationships compared to conventional analog techniques. In particular, Ribeiro et al.,(28) Revilla-León et al.(29) reported that digital CR recording systems may improve consistency and reduce operator-dependent variability compared to conventional methods. Li et al.(30) in a clinical case report, described the successful use of CAD/CAM workflows in full-mouth rehabilitation with favorable prosthetic fit and minimal adjustment needs. Jász et al.(31) confirmed that digital mandibular motion analyzers offer superior reliability in determining centric relation, especially compared to wax-based or operator-guided methods.

Diego Salgueiro (32) and Mangano (33) found that IOS systems excel over traditional impression materials such as PVS and alginate in terms of dimensional accuracy and surface detail. These scanners reduce common distortions typically seen in manual impressions, particularly in full-arch and edentulous cases. Additionally, Rutkūnas (34) and Tian et al.(35) explored the accuracy of bite registrations in edentulous and partially edentulous arches, demonstrating that the type of scanner and soft tissue mobility can affect occlusal precision. Nevertheless, digital methods continued to surpass conventional wax rim techniques in performance.

Numerous studies highlighted the clinical advantages of integrating 3D facial scanning with intraoral scanning (36). Hassan (37) and Garaicoa & Jurado (38) demonstrated how the combination of these technologies enables prosthetic designs that are both aesthetically pleasing and functionally harmonious. Wen et al.(39) utilized digital scanning to recreate Monson's curve in three dimensions, offering clinicians improved visualization of occlusal curvature and arch form.

CAD/CAM fabrication systems have been widely praised for their ability to create restorations with improved passive fit and occlusal integrity. Sadid-Zadeh (40) and Cristache (41) demonstrated that full-arch zirconia and hybrid implant prostheses fabricated digitally required less adjustment and provided better occlusal load distribution compared to conventionally cast frameworks. Similarly, Kreulen and Crins (42) reported that digital ceramic restorations needed minimal intraoral correction, resulting in faster delivery and higher patient satisfaction.

Computer-guided occlusal analysis tools, including T-Scan, have demonstrated improved diagnostic accuracy in various studies. Research by Majithia (43), Anandapandian & Raza (44), and Reich et al.(45) found that T-Scan technology offers measurable occlusal information—like force distribution, contact timing, and center of force—that traditional methods, such as articulating paper or foil, fail to capture. These insights facilitate more accurate occlusal adjustments in both natural teeth and prosthetic cases.

Several studies also examined workflow efficiency. Suganna (46) and Pekkan & Degirmenci (47) found that digital planning significantly decreased chairside time, fabrication errors, and patient visits.(48) Furthermore, Debbarma & Sharma (49) applied the Hobo technique in a digital context, confirming that occlusal philosophies traditionally implemented analog could be reliably adapted to digital workflows.

Finally, the reviews by Thimmappa et al.,(50) Suji et al.,(51) Devika & Thomas,(52) and Cortes (53) provided meta-analytical or summary insights, highlighting a significant clinical shift toward digital occlusal design. These studies have shown that digital methods are increasingly favored in both academic and clinical settings due to their accuracy, repeatability, and adaptability in complex rehabilitation cases.

The reviewed studies suggest that digital methods can improve occlusal accuracy and clinical efficiency in many cases, and may contribute to more streamlined, predictable, and aesthetically oriented treatment workflows. These results reflect the increasing integration of digital tools in modern prosthodontic and occlusal rehabilitation practices.

Table 1. Summary of included studies in Result

Articles	Research focus	Summary of findings
Ribeiro et al. (28) Revilla-León et al.(29) Li et al.(30) Jász, B. (31)	Digital CR Recording and Jaw Relation Accuracy	Digital CR tools reduce operator error and increase consistency in jaw relation recording
Salgueiro (32) Mangano (33) Rutkūnas, V.(34) Tian et al. (35)	Intraoral Scanner (IOS) Accuracy	IOS improves dimensional accuracy over conventional impressions; scanner type and tissue mobility influence precision
Hassan (37) Garaicoa & Jurado (38) Wen et al. (39)	3D Facial Scanning and Aesthetic Integration	Facial and intraoral scanning integration improves aesthetic-functional outcomes and visualizes occlusal curves
Sadid-Zadeh & Liu (40) Cristache (41) Kreulen and Crins (42)	CAD/CAM Fabrication and Occlusal Fit	Digitally fabricated prostheses offer better occlusal load distribution, passive fit, and need less adjustment.
Majithia (43) Anandapandian & Raza (44) Reich et al. (45)	Digital Occlusal Analysis with T-Scan	T-Scan provides quantifiable occlusal data (force, timing) for more accurate adjustments than traditional methods

Articles	Research focus	Summary of findings
Suganna et al. (46) Pekkan & Degirmenci (47) Debbarma & Sharma(49)	Workflow Efficiency and Digital Adaptation of Analog Techniques	Digital workflows reduce chairside time and errors; traditional occlusal concepts like the Hobo technique adapt well digitally
Thimmappa et al.(50) Suji et al. (51) Devika & Thomas (52) Cortes (53)	Systematic Reviews and Meta-Analyses	Meta-reviews highlight the clinical shift to digital methods due to enhanced accuracy, repeatability, and application scope

IV. Discussion

Digital technology has truly transformed the way we approach planning, designing, and delivering full-mouth rehabilitation. It empowers clinicians to record and reproduce occlusal relationships with an amazing level of precision and accuracy. This review synthesizes findings from 52 selected studies and several recent open-access publications to evaluate how digital methods improve occlusal accuracy, streamline workflows, and compare with conventional approaches. The discussion is organized to directly address the five primary research questions posed in this study.

4.1. How do digital methods affect occlusal discrepancies in full-mouth rehabilitations?

Occlusal discrepancies in traditional full-mouth rehabilitation frequently occur because of distortions in physical impressions, inaccuracies in bite registration, and operator-dependent errors during jaw relation transfer. Digital workflows have shown significant advantages in reducing these discrepancies by eliminating many analog variables.

Multiple studies in this review Ribeiro et al.(28), Zhang et.al.(54), Ragazzini & Baldissara (55), confirmed that digital jaw relation records, when combined with intraoral scanning and CAD-based articulation, yield highly reproducible results with enhanced centric relation (CR) accuracy. Li et al.(30) and Revilla-León et al.(1) revealed that handheld scanners and jaw-tracking tools capture edentulous jaw relations more consistently than traditional methods.

Recent open-access research supports this conclusion. For instance, Ren et al.(56) found that a comprehensive digital workflow utilizing an auxiliary occlusal device substantially enhanced crown fit and minimized occlusal errors in multi-implant cases compared to traditional techniques. Similarly, Mishra et al.(57), Hanqi Gao (58) reported that digital workflows in full-mouth implant rehabilitation reduced working time and minimized occlusal adjustments.

Huanhuan Liu (59) reported that a fully digital CAD/CAM workflow enabled precise control of restoration and stable jaw relationship transfers throughout full-mouth rehabilitation stages.

4.2. What are the key advantages of digital workflows in reducing occlusal discrepancies compared to conventional techniques?

Digital workflows provide numerous clinical benefits compared to traditional techniques, particularly in enhancing the accuracy of occlusal contacts and restoring functional harmony. Intraoral scanners Mangano (33) , Revilla-León et al.(60) digital smile design Hassam (61), Garaicoa & Jurado (38), and CAD/CAM fabrication Kreulen & Crins (42) have proven to minimize the need for adjustments within the mouth and rework after delivery, making the process smoother and more efficient.

The reproducibility of digital-centric relation records has been demonstrated by Ribeiro et al.(28) and Jász et al.(31), even in edentulous patients, Rutkūnas et al.(34), Tian et al.(35), and for re-establishing occlusal relationships in patients with maxillofacial fractures, Wang et al.(62), enabling more predictable occlusal outcomes. Digital articulation systems like ModJaw and virtual articulators enhance the simulation of mandibular dynamics, as shown by Almadi et al.(63), reducing occlusal interferences and improving bilateral functional balance.

Recent studies support these findings. A meta-analysis by Mahato et al.(64) concluded that digital workflows are not only more efficient but also produce superior clinical outcomes regarding occlusal fit and esthetics. Karasan et al.(65) further discovered that prostheses made using digital techniques needed considerably less chairside occlusal adjustment compared to those created conventionally.

4.3. How do intraoral scanners and digital articulation software contribute to better occlusal balance?

Intraoral scanners (IOS) and digital articulation software greatly improve occlusal balance by enhancing the precision and consistency of data collection, virtual mounting, and dynamic occlusal assessment analysis. Studies by Mangano (33), Ender, A (66), Jin et al.(67) demonstrate that iOS systems minimize dimensional distortion, enhance arch alignment, and enable real-time assessment of occlusion relationships. Their capability to capture high-resolution digital impressions enables

real-time visualization and verification of occlusal contacts, significantly reducing the cumulative errors typically associated with conventional impressions.

Furthermore, digital articulation software—especially when combined with jaw motion tracking technologies—provides a more physiologically accurate simulation of mandibular movements. Virtual articulators and jaw motion tracking devices—used by Revilla-León et al.(29), Wen et al.(39), and Blasi et al.(68) — enable dynamic occlusal analysis and more physiologically accurate reconstructions. This is especially advantageous in full-arch implant cases and orthognathic surgery, where mandibular repositioning and occlusal stability are crucial Almadi et al.(63), Park et al.(69)

In addition, digital occlusal analyzers such as T-Scan improve clinical decision-making by providing objective metrics on occlusal contact timing, force distribution, and center of pressure. Majithia (43), Reich et al.(45), and Anandapandian & Raza (44) demonstrated that these systems can detect early contacts and occlusal interferences that traditional techniques like articulating paper often miss. By delivering measurable feedback, these tools enable more accurate occlusal adjustments and minimize the chances of functional discrepancies after treatment. The combination of IOS, digital articulation, and computerized occlusal analysis promotes a more reliable, individualized method for achieving and sustaining optimal occlusal balance in both prosthodontic and surgical procedures.

4.4. What are the limitations and challenges of using digital occlusal analysis in clinical practice?

Despite their advantages, digital occlusal tools have several challenges that remain in daily clinical practice. Studies such as those by Thimmappa et al.,(50), Rosa et al.(70), and Cortes (53) it was pointed out that the high cost of equipment and software can be a barrier; moreover, clinicians must overcome a significant learning curve, as properly using digital systems requires familiarity with both the hardware and the associated digital workflows. In addition, digital tools often struggle to simulate natural jaw joint (TMJ) movements fully. Another challenge is capturing a reliable centric relation (CR), especially in edentulous patients. Tian et al.(35) and Lee et al.(71) It was reported that the mobility of soft tissues and variability in scanners can reduce the accuracy of virtual occlusal records in patients lacking fixed landmarks. Chandraker et al.(72) documented similar

limitations in edentulous patients, in which achieving reliable digital impressions and jaw relation records proved to be technically more challenging.

Still, Technology is improving. AI-based jaw tracking, enhanced scanner calibration, and the integration of digital tools with traditional methods are working to reduce these issues and make digital occlusal analysis more reliable in the future.

4.5. What future developments are needed further to enhance the precision of digital occlusion in full-mouth rehabilitations?

Future advancements in digital occlusion are anticipated to emphasize enhancing full-mouth rehabilitations to be even more accurate, efficient, and personalized. Devika & Thomas (52) emphasized how AI can assist in predictive occlusal planning by automating adjustments and reducing manual effort errors. Lobo (73) discussed the integration of haptic feedback into digital articulators, enabling clinicians to experience tactile responses during virtual occlusal adjustments. Wu et al.(74) highlighted the advantages of real-time feedback during scanning and design, improving digital workflow accuracy.

Fabrication technologies are also advancing. Methani & Cesar (75) showed that additive manufacturing enhances the speed and fit of prostheses, and stackable guided templates, while Cristache (41) introduced stackable guided templates that support accurate surgery and immediate loading. Papaspyridakos et al. (76) described protocols that completed full-arch rehabilitations in as few as three visits, integrating digital planning with immediate loading and real-time occlusal control.

New systems that can simulate dynamic occlusion and utilize biometric feedback, such as motion capture and EMG input, have the potential to greatly enhance the personalization and predictability of occlusal rehabilitation in intricate cases.

Table 2. Grouped findings by research focus are summarized

Articles	Research focus	Summary of findings
Ribeiro et al. (28) Zhang et al. (54) Ragazzini & Baldissara (55) Li et al. (30) Revilla-León et al. (1) Ren et al. (56) Mishra et al. (57) Hanqi Gao (58) Huanhuan Liu (59)	Impact of Digital Methods on Occlusal Discrepancies	Digital workflows significantly reduce occlusal discrepancies by improving jaw relation recording accuracy, minimizing impression distortions, and reducing operator error. Enhanced fit and fewer occlusal adjustments were observed in full-mouth implant and multi-unit cases
Mangano (33) Revilla-León et al.(60) Hassam (61) Garaicoa & Jurado (38) Kreulen & Crins (42) Wang et al.(62) Jász, B. (31) Rutkūnas et al.(34) Tian et al.(35) Almadi et al.(63) Mahato et al.(64) Karasan et al.(65)	Advantages of Digital Workflows in Reducing Occlusal Discrepancies	Digital tools like IOS, DSD, and CAD/CAM enhance occlusal contact accuracy, reproducibility in CR records, and reduce intraoral adjustments. Meta-analyses confirm improved efficiency and esthetics with fewer occlusal errors

Articles	Research focus	Summary of findings
Ender, A (66) Jin et al.(67) Wen et al.(39) Blasi et al. (68) Park et al. (69) Majithia (43) Reich et al.(45) Anandapandian & Raza (44)	Contribution of IOS and Digital Articulation to Occlusal Balance	IOS and digital articulators improve real-time visualization, reduce distortions, and simulate jaw movements more accurately. T-Scan systems provide quantifiable occlusal data, aiding precision in prosthetic and surgical cases
Thimmappa et al.,(50) Rosa et al.(70) Cortes (53) Lee et al.(71) Chandraker et al.(72)	Limitations and Challenges of Digital Occlusal Analysis	Challenges include high costs, steep learning curves, and reduced accuracy in CR recording for edentulous patients. Limitations arise from scanner variability and soft tissue mobility, especially when TMJ simulation is required
Devika & Thomas (52) Lobo (73) Wu et al (74) Methani & Cesar (75) Cristache (41) Papaspyridakos et al. (76)	Future Developments in Digital Occlusion	AI, haptic feedback, and real-time design feedback aim to improve accuracy and reduce manual effort. Additive manufacturing and guided templates support faster, more precise prosthesis delivery and surgical planning

4.6. Limitations

- A significant portion of the studies analyzed were model-based or in vitro, which restricts their capacity to mirror the intricate intraoral conditions found during full-mouth procedures rehabilitations.
- Publication bias cannot be excluded, as no funnel plot or Egger's test was conducted; therefore, studies yielding negative or neutral results may be underrepresented.
- Long-term follow-up data is limited, only few studies surpassing 12 months, hindering assessment of the long-term functional stability of digital occlusal workflows.
- Only four studies concentrated on completely edentulous patients, which restricts the applicability of results to full-arch implant or denture situations.
- Many digital systems require specific calibration, pre-conditioning, or familiarity with software; variability in protocols can decrease reproducibility across clinics.

4.7. Summary

Digital dentistry has revolutionized full-mouth rehabilitation by increasing occlusal precision, minimizing discrepancies, and streamlining workflow efficiency. This review demonstrates that when used correctly, digital tools yield more reliable, patient-focused results than traditional analog techniques. Although there are still challenges, continuous technological progress is swiftly bridging these gaps, indicating a future where entirely digital occlusal management could become the benchmark in intricate prosthodontic treatments.

V. Conclusion

The findings of this review clearly demonstrate that digital methods have transformed the field of full-mouth rehabilitation, particularly in managing occlusal relationships. By replacing analog workflows with precise, reproducible, and data-driven digital systems, clinicians can achieve enhanced accuracy in jaw relation records, occlusal analysis, and prosthetic fabrication. Digital tools, such as intraoral scanners, CAD/CAM systems, digital centric relation recording, and computer-guided occlusal analysis platforms like T-Scan, significantly reduce the common sources of occlusal discrepancies typically observed with conventional techniques.

The integration of virtual articulators and mandibular motion tracking systems enables dynamic occlusal simulation, while digital smile design and 3D facial scanning promote esthetic and functional harmony. Clinical studies consistently demonstrate that these technologies enhance occlusal balance, decrease chairside adjustment time, and improve patient satisfaction. Furthermore, the digital workflow provides increased efficiency and fosters better interprofessional collaboration between clinicians and dental laboratories.

Despite these advantages, limitations such as scanner variability, challenges in edentulous arches, cost barriers, and the learning curve associated with new software remain. However, ongoing advancements—particularly the emergence of AI-powered occlusal prediction, dynamic TMJ modeling, and biometric feedback integration—are anticipated further to enhance accuracy, accessibility, and clinical outcomes.

In conclusion, digital occlusal workflows represent a paradigm shift in full-mouth rehabilitation, offering higher precision, predictability, and patient-centered care. As technology evolves, adopting comprehensive digital protocols will likely become essential to the future of advanced prosthodontics and restorative dentistry.

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Abstract in Korean

전악 수복에서 교합 정확도를 향상시키는 디지털 기법의 효과는 얼마나 뛰어난가?

목적: 본 리뷰의 목적은 전악 수복 치료에서 교합 이상을 최소화하는 데 있어 디지털 기법의 효과를 평가하는 것이다. 본 논문은 구강 내 스캐닝, 디지털 악간 관계 기록, 컴퓨터 기반 교합 분석 등 디지털 워크플로우를 전통적인 아날로그 방식과 비교하여 정확성, 재현성, 임상 결과의 향상 여부를 분석하였다. 또한 디지털 기법의 한계점을 살펴보고, 보철 진료에서 교합 정확도를 향상시키기 위한 향후 연구 방향을 제시하고자 한다.

재료 및 방법: 2010 년부터 2025 년까지 발표된 문헌을 대상으로 PubMed, Scopus, ScienceDirect 에서 포괄적인 문헌 검색을 수행하였다. 총 310 편의 논문이 스크리닝되었으며, 이 중 52 편이 선정 기준을 충족하였다. 포함된 연구는 디지털 교합 기록 기법을 평가하거나 디지털 워크플로우와 기존 방식 간의 비교, 혹은 교합 정확성과 관련된 임상 결과를 다룬 논문들이다. 선정된 논문에 대해 자료 추출 및 주제별 종합 분석을 실시하였다.

결과: 총 52 편의 연구는 디지털 방식이 전통적 기법에 비해 전악 수복에서 교합 정확성, 재현성, 진료 효율성을 유의미하게 향상시킨다는 점을 보여주었다. 구강 내 스캐너, 디지털 중심위(CR) 기록 장치, 가상 교합기 등의 기술은 특히 무치악이나 복잡한 증례에서 우수한 성과를 보였다. CAD/CAM 시스템은 보철물의 적합도를 개선하고 조정 필요성을 줄이며, T-

Scan 기술은 정량적인 교합 데이터를 제공한다. 디지털 워크플로우는 전반적으로 더 빠르고 정밀하며, 환자 중심의 결과를 가능하게 한다.

결론: 디지털 교합 기법은 기존 방식에 비해 정밀성과 효율성 면에서 뚜렷한 장점을 제공한다. 인공지능(AI), 가상 교합기와 같은 최신 기술은 임상 효과를 더욱 향상시키고 있으나, 무치악 사례에서의 적용에는 여전히 일부 한계가 존재한다.

핵심 되는 말: 디지털 교합, 전악 수복, 디지털 기법, 교합 이상, 악간 관계, 디지털 기법을 활용한 교합 정확도