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Review Article

Prosthetic replacement and occlusal efficacy – A systematic review

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Abstract

Aim: To assess the occlusal efficacy of CAD-created occlusal anatomy and hand layered occlusal anatomy in fixed dental prosthesis using Digital occlusal analysis (T-scan) in literature.

Methods and Materials: To find the studies under consideration, detailed search plans were created for each database used (i.e. PubMed central, Google and Hand Search) till January 2022. Studies that compare different materials for CAD-CAM crowns, studies using digital occlusal analysis, studies comparing occlusal and disocclusal timing using T-scan, clinical trials and prospective studies were considered for this review.

Results: Out of 119 articles obtained from the electronic search, 97 were excluded because their titles and abstracts were not related to the topic, and 10 were excluded due to missing important data. In the end, 12 articles were reviewed. The PRISMA chart shows how the articles were chosen for this review, which compared prosthetic replacement and occlusal efficacy using a digital occlusal analysis.

Conclusion: This review concludes that the studies considered have a high risk of quality bias. However, results of included studies concluded that there was a significant difference in using T-scan for occlusal equilibration for fixed dental prosthesis – CAD-created and hand layered occlusal anatomy and is a reliable tool as it shows the Occlusal and Disocclusal Timing and the Intensity of Contact load in percentage compared with the traditional articulating paper. Hence further clinical trials need to be conducted with proper sample size calculation, blinding and randomization to obtain accurate results.

Keywords: Crowns, Ceramics, Computer aided design, Computer aided manufacturing, Dental occlusion.

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1. Introduction

Occlusion is vital in dentistry.[1] Any dental restoration aims to bring occlusion to its original functional balance.[2,3] Small changes in how forces are distributed can usually be adjusted by the stomatognathic system. The biting surface of a prosthesis is typically designed based on how the teeth come together when not moving.[3] However, when the patient's bite during movement is tested at the clinical try-in phase, bite interferences can appear.[4-6] If these force changes go beyond what the body can handle, they may cause various problems. That's why it's relevant to accurately detect and correct any bite interferences.

Using articulating paper to make adjustments depends on the dentist's judgement and the patient's sense of how their bite feels. However, their accuracy is questionable.[7] Literature analysing physical properties of articulation paper is available, but those assessing varying occlusal loads via articulation paper mark size, or appearance characteristics are unavailable.[8,9]

Tekscan, a digital analysing system, objectively assesses occlusal equilibration.[10] It measures the strength of bite forces and provides numeric values to assess how balanced the bite is, including how long the teeth stay in contact (OT - occlusion time) and how quickly they separate (DT - disocclusion time).

There are few studies comparing the occlusal efficacy of CAD created prosthesis in FPD using digital occlusal analysis.[11-13] The purpose of the current review is to compare the occlusal efficacy of CAD created occlusal anatomy to that of hand layered using digital occlusal analysis.

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1.1. Research question

Is there any difference in how well the bite functions between CAD-designed occlusal surfaces and hand-layered ones in fixed dental prostheses?

2. Materials and Methods

2.1. Literature search protocol

The systematic review was performed based on PRISMA Guidelines. To find relevant studies, a detailed search plan was created using a mix of MeSH terms and important keywords. These were grouped into four main categories, namely, Population, Intervention, Comparison and Outcome.

P-Missing teeth, Fixed dental prosthesis, Fixed partial prosthesis, Fixed Partial crowns, All-Ceramic Restorations, Full veneer crowns, Zirconia crowns, CAD-CAM crowns, Monolithic crowns, Full mouth rehabilitation, Feldspathic crowns, I-CAD CAM Crowns (Monolithic crown), Zirconia crowns, Monolithic zirconia, lithium disilicate; zirconia-reinforced lithium silicate, Digitally veneered crowns, Milled crowns, CAD Created crowns C-Zirconia Copings veneered with Feldspathic porcelain, All-ceramic crowns, Milled copings, Hand layered ceramic crowns, manually layered crowns, O-T-scan, T-Scan Novus, T-scan III, Tekscan, Digital occlusal analysis, Occlusal contact loading, Occlusion Timing.

Keywords in each group were linked using the word 'OR', and the different groups were then combined using 'AND' to search for articles online up to January 2022.

2.2. Databases explored

Thorough search methods were used across the following databases.

1. National Library of Medicine (PubMed)
2. Pubmed advanced search
3. Cochrane database
4. Google scholar

2.3. Language restrictions

No limits and language restrictions were applied during the electronic search to include the search phase of the systematic review. No time restriction was applied.

2.4. Hand search

Additionally, hand searching was done in the following journals

1. The Journal of Craniomandibular & Sleep Practice
2. The International Journal of Prosthodontics
3. Journal of Oral Rehabilitation

2.5. Inclusion criteria

Criteria for considering studies for this review:

1. Studies that compare different materials for CAD-CAM crowns
2. Studies that use digital occlusal analysis
3. Studies that compared occlusal and disocclusal timing by using T-scan
4. Clinical trials, prospective studies.

2.6. Exclusion criteria

The following studies were excluded:

1. In vivo studies
2. Studies which do not include digital occlusal analysis
3. Case reports
4. Patients treated using implant cases

2.7. Description of studies

The search identified 12 publications that were relevant to the title (**Figure 1**).

A total of 12 publications that fulfilled the criteria were considered in this review (**Table 1**).

2.8. Quality assessment

The authors conducted a quality evaluation using the Cochrane Collaboration tool to assess the risk of bias (**Table 2**). All the selected articles were assessed by the first and second authors. The studies were evaluated using seven domains and were rated further as a risk of bias (low, medium and high) by the investigators (as shown in **Table 2**).

2.9. Outcome variables

The outcomes of interest in this SR are occlusal discrepancy among crowns fabricated through various systems, occlusal contact verification and the effect of digital occlusal analysis on occlusion (Higgins and Green. Cochrane reviewer's Handbook 2009).

3. Results

One review author selected randomized trials that met the inclusion criteria for this review. Two authors then extracted data and evaluated the study quality. The agreement between the reviewers on methodological quality was assessed using the kappa statistics with quadratic weights.

Out of the 119 articles obtained from electronic search, 97 were excluded because their title and abstract were not relevant to our topic, and 10 were excluded due to missing core data. A total of 12 articles were included following the PRISMA guidelines for this systematic review.

Table 1: Description of studies

Author	Year	Study design	Level of evidence
Sateesh B Haralur	2013	In vivo	Level 1b
Sarah Qadeer	2016	In vivo	Level 1b
Teresa	2015	In vivo	Level 1b
Reddy Chaitanya	2018	In vivo	Level 1b
Ping-ting Lin	2017	In vivo	Level 1b
Satheesh B. Haralur	2018	In vivo	Level 1b
Teresa Sierpinska	2016	In vivo	Level 1b
Emily R. Batson	2014	In vivo	Level 1b
Rane V	2017	In vivo	Level 1b
Kohyama K	2004	In vivo	Level 1b
Duygu Karakis	2021	In vivo	Level 1b
Min-Young Jeong,	2020	In vivo	Level 1b

Table 2: Risk of bias

Article	Randomistaion	Allocation	Selective Reporting	Other Bias	Blinding of Participant	Blinding of outcome assessment	Incomplete Outcome Data
Sateesh B Haralur	No	No	No	Unclear	No	No	No
Reddy chaitanya	No	No	Yes	Yes	No	No	Yes
Ping-ting Lin	Yes	Yes	No	Unclear	Yes	Yes	No
Sarah qader	No	No	Yes	Yes	Yes	Yes	Yes
Teresa	No	No	No	Unclear	Yes	Yes	No
Emily R. Batson	Yes	No	Yes	Unclear	No	No	Yes
Sateesh B Haralur	No	No	Yes	No	No	No	No
Teresa Sierpinska	No	No	No	Unclear	Yes	Yes	No
Rane V	No	No	Yes	Unclear	Yes	Yes	Yes
Kohyama K	No	No	Yes	Unclear	Yes	Yes	Yes
Min-Young Jeong,	No	No	Yes	Unclear	Yes	Yes	Yes
Duygu Karakis	No	No	Yes	Unclear	Yes	Yes	Yes

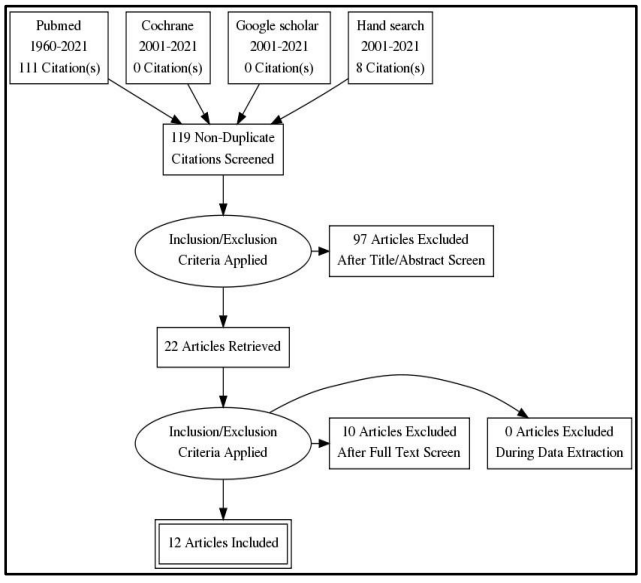

Figure 1: Search flowchart

4. Discussion

This systematic review evaluated 12 articles published between 2004 and 2021, all classified as Level 1b evidence. Effect of occlusal anatomy on contacts, occlusal contact verification, digital occlusal system, effect of crown or bridge anatomy on occlusal contact and effect of different types of prosthesis on the occlusal contact have been discussed.

4.1. Effect of occlusal anatomy on contacts

Occlusion is difficult to evaluate due to the absence of a clear gold standard. A successful occlusal surface design should not drastically alter the existing bite in cases of simple restorations such as a single crown.[14] The occlusal contact established should be similar to what it was before preparation. The study found a strong link between the contact area and the Preferred Chewing Side (PCS), showing that the contact area on the PCS was larger than on the opposite side. These results are consistent with Yurkstas et al., who reported greater masticatory efficiency on the preferred chewing side (PCS).[15] Chewing efficiency has been linked to the size of the occlusal contact area within the same person.[16] Masticatory efficiency is ideally maximized by the

multi-cusped design of dental occlusal surfaces, which increases the size of the contact area in posterior tooth crowns and helps distribute occlusal forces more effectively. The force on each cusp is less than the vertical force generated from elevator muscles.[17] This biomechanical arrangement reduces stress on periodontal tissues during clenching. For occlusal stability, the maximum voluntary clench should be recorded, as at lower levels of clenching intensity, the bite force tends to shift towards a more balanced bilateral position.[18] Additionally, when clenching without food, there are more tooth contacts with firm pressure than with light pressure

4.2. Occlusal contact verification

Occlusal contact verification is typically marked using articulating paper, where a central area remains color-free, surrounded by a dense peripheral rim. These marks are sometimes called "target," "bull's eye," or "iris" by different authors.[19] Many occlusion textbooks suggest that the marked area reflects the load exerted at that point.[20] Darker, larger marks are thought to indicate heavier occlusal loads, while smaller, lighter marks suggest lighter loads.[21] A series of similarly-sized marks on adjacent teeth is believed to show equal intensity, evenness, and timing of the occlusal contact. Practitioners often rely on these markings to identify areas needing correction. However, in some cases, a small mark may correspond to a high concentration of force, while large, dark marks might not indicate much force at all. While articulating paper is commonly used, its marks can be influenced by the width of the paper and the salivary presence, which can cause the ink to spread and lead to false positives.[22]

Transillumination of silicon bite registration offers a solution to some of these issues, but the results depend heavily on the direction of the light and can be affected by the type of filler in the bite registration material.[23]

4.3. Digital occlusal system

Maness introduced the T-scan system as a computerized tool for analyzing occlusion and published the first related study in 1987.[24,25] Since the launch of the original T-scan I in 1984, the technology has evolved significantly over the past 30 years, with versions like the T-scan II for Windows (1995), T-scan III with turbo recording (2004), and the most recent T-scan v10 (2018). Compared to traditional methods, the T-scan offers the advantage of showing real-time changes in bite force using an intraoral sensor. The sensor foil is 100 micrometers thick and contains conductive lines forming a grid of small, pressure-sensitive squares known as sensels.[26-30] When force is applied, the voltage in these sensels change, and the T-scan software converts this data into a digital display.

Accura (Dmetec Co., Bucheon, Korea) is a new computerized occlusal analysis system that shows the change of occlusal force in real-time, similar to the T-scan. According to the manufacturer's information, it can measure the absolute occlusal force. The sensor film is made of polyimide and is 160-μm thick. The device is connected to the computer through Wireless Fidelity (Wi-Fi) for data transfer.

However, there are only a few studies that compared different digital occlusal analyses and according to the study by Min-Young Jeong et al., the new Accura system demonstrates similar accuracy to the T-scan in detecting occlusal contacts at maximum intercuspation.[30] However, there are some differences between the two systems in terms of their sensor films and the spatial resolution of their sensels.

However, Vivek Rane et al. invented a new occlusal analysis that evaluates the Occlusal Forces Data in graphical representation and development of bite force system based on Analogue to Digital Converter (ADC) along with fully featured microcontroller system and PC based software which he claims to be highly accurate, fast with high resolution and there are no comparative studies on this device.[31]

4.4. Effect of crown or bridge anatomy on occlusal contact

Occlusal awareness, or the ability to sense contact between teeth, is primarily governed by mechanoreceptors located in the periodontal ligament. When this ligament is absent, such as in cases involving implants, sensory feedback is instead provided by muscle spindle receptors in the jaw-closing–muscles and the temporomandibular joint (TMJ). In natural teeth, the ability to detect contact–known as interocclusal tactile sensitivity–typically ranges between 15 and 30 micrometers.[27,32,33] However, when a natural tooth is opposed by a fixed dental prosthesis, this sensitivity decreases to around 63 micrometers. For cases where both opposing teeth are prosthetic, the sensitivity further drops to approximately 66 micrometers.

This reduction in sensitivity is thought to be due to changes in the tooth's mechanical behavior following the placement of rigid restorations. Sealing of the dentinal tubules by crowns or other restorations may influence the tooth's viscoelastic response and disrupt the natural hydrodynamic flow, which plays a role in sensory function. Additional contributing factors may include trauma to the pulp or periodontal tissues as a result of dental procedures.[28,29,32-35] These changes can make it more difficult for patients to accurately detect occlusal interferences when biting on prosthetic restorations.

Moreover, traditional methods like articulating paper are limited in their ability to reflect true bite force, as they cannot indicate the intensity of pressure or distinguish between early and late contacts. As a result, articulating paper-based adjustments depend on patients' subjective perception of occlusion, introducing variability and limiting accuracy. This

variability may lead to an imbalance in occlusal forces following prosthetic treatment.

4.5. Effect of different types of prosthesis on occlusal contact

According to research by Zhang et al., a comparison was made between monolithic zirconia crowns designed using the correlation method and those designed using the library method.[32] The study found that crowns fabricated with the correlation approach demonstrated improved eccentric occlusal function and exhibited fewer lateral interferences. Furthermore, this method resulted in a higher relative occlusal force, thereby contributing to the restoration of the original occlusal dynamics. In a separate comparative analysis of prosthetic designs, digital occlusal analysis revealed that fixed partial dentures (FPDs) produced a more symmetrical distribution of bite forces across the dental arch compared to removable partial dentures (RPDs).[33]

Hence, T-Scan may be a better option to identify and eliminate occlusal interferences in CAD-CAM occlusal anatomy and in hand layered occlusal anatomy, clearly when compared to the traditional use of articulating paper.

5. Conclusion

With the available evidence from the included studies, the quality of the clinical trials was moderate. The results of included studies concluded that there was a significant difference in using T-scan for occlusal equilibration for fixed dental prosthesis and hence the null hypothesis was rejected. However, a greater number of clinical trials adhering to the correct method of randomisation, allocation concealment and blinding have to be carried out to arrive at a definitive conclusion. T-scan is a good reliable tool for occlusal equilibration as it shows the Occlusal and Disocclusal Timing and also the Intensity of Contact load in percentage compared with the traditional articulating paper. In future, with digitalisation in dentistry, with the help of occlusal analysis at various stages (before tooth preparation and after tooth preparation) and applying the same data digitally, fabrication of precise CAD-CAM crowns which do not necessitate occlusal equilibrations may be possible.

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7. Conflict of Interest

None.

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