Rev Estomatol. 2025; 33(1):e14074 DOI: 10.25100/re.v33i1.14074

Revista Estomatología

ORIGINAL ARTICLE

Qualitative Evaluation of 3D Resin and Acrylic Occlusal Splints in the Treatment of Temporomandibular Disorders: A Pilot Study

Fernanda Montserrat Beltrán Meléndez [1] | Víctor Mario Fierro Serna [1] | Alan Martínez Zumaran [1] | Rita Elizabeth Martínez Martínez [1] | Felipe García Cruz [1] | Ricardo Martínez Rider [1] | Víctor Emanuel Martínez Urbina [1] | Marco Felipe Salas Orozco [1]

OPEN ACCESS

Institutional Affiliation

[1] Universidad Autónoma de San Luis Potosí, Faculty of Stomatology, San Luis Potosí, México.

Citation:
Beltrán Meléndez F.M., Fierro Serna V.M., Martínez Zumaran A., Martínez Martínez R., García Cruz F., Martínez Rider R., Martínez Urbina V.E., Salas Orozco M.F. Qualitative Evaluation of 3D Resin and Acrylic Occlusal Splints in the Treatment of Temporomandibular Disorders: A Pilot Study. *Rev Estomatol.*2025; 33(1):e14074. DOI: 10.25100/re.v33i1.14074

Received: 13th May 2024
Evaluated: 15th December 2024
Accepted: 3th March 2025
Published: 7th April 2025

Correspondence author: Marco Felipe Salas. Benemérita Universidad Autónoma de Puebla, Faculty of Stomatology, Department of Orthodontics, Puebla, México. Pue 72410, México. Email: marco-salas@hotmail.com

Keywords: Temporomandibular disorders; occlusal splints; 3D printing; PMMA.

Copyright:
© Universidad del Valle.
CC BY NC ND

ABSTRACT

Introduction: This study addresses the increasing application of digital technologies in dentistry, specifically in the fabrication of occlusal splints for the treatment of temporomandibular disorders (TMD). It investigates the effectiveness, fit, and comfort of splints made using conventional and digital methods (3D resin and acrylic), considering the importance of precision in TMD treatment.
Methodology: The research was conducted with a sample of ten patients, evaluating the splints in terms of retention, adaptability, tilting, and the need for reprinting. Conventional and digital splints were compared using qualitative measurements and patient satisfaction as indicators.
Results: Conventional splints demonstrated solid performance across all evaluated categories. However, a digital splint initially presented fitting problems, requiring reprinting. Despite this, digital splints showed significant advantages in precision and efficiency after necessary modifications, with high patient acceptance.
Conclusions: The research highlights the potential of digital techniques in the fabrication of occlusal splints, suggesting superiority in terms of adaptability and patient satisfaction, despite initial fitting challenges. This study underscores the importance of technological innovation in improving dental care for TMD patients, recommending greater adoption of digital methods in clinical practice.

INTRODUCTION

Temporomandibular disorders (TMD) encompass a variety of conditions affecting the temporomandibular joints, masticatory muscles, and related structures. These disorders are a common source of chronic orofacial pain, significantly impacting patients' quality of life. One prevalent treatment for TMD involves the use of occlusal splints, devices designed to improve the mandible's position and function.[1]

Historically, occlusal splints have been manufactured using analog methods, with thermocured acrylics as the primary material. Although effective, this approach has limitations in terms of customization and fit. With the advancement of digital technology, 3D printing has emerged as a promising alternative, offering advantages in precision, production time, and customization possibilities. Nonetheless, comparative evidence between these two methodologies in occlusal splint manufacturing, particularly for TMD patients, remains scarce.[2]

This study presents a comparative analysis between the use of 3D printing resin in a digital workflow and thermocured acrylic in an analog workflow, focusing on the production of occlusal stabilization splints for TMD patients. It aims to assess not just the clinical efficacy of both methods, but also factors such as fit precision, patient comfort, and production time efficiency.

The importance of this research lies in its potential to influence clinical practice. By comparing these two technologies, the study seeks to identify the most effective and efficient method, aiming to enhance patient care and optimize clinical resources. This investigation contributes to the dental and maxillofacial surgery fields and provides new perspectives on integrating digital technologies into healthcare.

MATERIALS AND METHODS

This observational, analytical, longitudinal, and prospective study was carried out at various facilities of the Faculty of Stomatology at the Autonomous University of San Luis Potosí (UASLP), including the Maxillofacial Surgery Clinic, the Orthodontics and Dentomaxillofacial Orthopedics Clinic, the Digital Laboratory, and the Prosthesis Laboratory. Participants were selected through non-probabilistic consecutive sampling, focusing on patients diagnosed with temporomandibular disorder (TMD) between May and June 2023.

The sample size was set at 10 patients for this pilot study. Participants were divided into two groups: Group A used thermocured acrylic guards, and Group B used E-Guard resin printed guards. Inclusion criteria included TMD diagnosis, age 14 to 59 years, natural dentition or fixed prostheses, and a maximum of one missing molar per hemiarch. Exclusion criteria were total edentulism, orthodontic treatment, refusal of informed consent, and severe periodontal disease. Elimination criteria included missing control appointments, withdrawal from the study, non-adherence to treatment, or any situation preventing variable measurement.

The fabrication of occlusal guards involved conventional and digital workflows. The conventional method started with impressions using standard metal trays and alginate, followed by disinfection with 70% alcohol. A bite registration in centric relation was achieved using a four-part tongue depressor as an anterior deprogramming device, facilitating neuromuscular deprogramming. Patients were instructed to bite into softened blue Delare wax for the bite registration, which guided the jaw into centric relation. The final registration was taken without allowing the patient to close their mouth fully. Alginate impressions were cast in type IV gypsum to create master models, which were mounted on an AD2 articulator. The occlusal guard was designed in wax, incorporating anterior guidance and bilateral multiple contacts, without posterior contacts in protrusive or lateral movements. The wax design was transferred to transparent polymethylmethacrylate (PMMA) using an injection molding method. The finished guards were polished, ensuring a smooth and aesthetically pleasing finish, ready for clinical evaluation.

The digital splint fabrication for this study began with high-precision optical impressions of the upper and lower jaws using a 3Shape TRIOS 3 Wired intraoral scanner, following the manufacturer's recommended methodology. Despite using blue wax for occlusion registration, like the conventional method, it was necessary to trim the wax to expose areas of interest for scanning to ensure adequate capture by the device. After scanning and obtaining digital impressions, the splint design was conducted using 3Shape Splint Studio software. STL files of the upper and lower models were imported into the program for virtual mounting on a digital Artex articulator. This virtual process allowed for precise adjustment of the condylar inclination and axis, setting the axis at 45° for both sides and the condylar inclination at 15°. Detailed attention was paid to the splint design, starting with selecting the jaw to work on and blocking retention areas with virtual wax. Special care was given to defining the margin line, flaring it posteriorly at the prosthetic equator level for optimal retention and outlining it anteriorly over the incisal edges for comfort and aesthetics. The insertion direction was verified through the software, suggesting adjustments to maintain flexibility in margin line design when necessary. The splint's thickness was kept to a minimum of 0.4 mm as recommended by the software, establishing proper contact with each tooth in the intercuspal position. Canine and anterior guides were designed to allow correct articular movement, angled at 30 degrees to simulate occlusal ramps. The design process lasted between 30 to 60 minutes, depending on the patient's occlusal complexity and dental axis variations. Once completed, a smoothing command was used to ensure a smooth surface and avoid overly tight adjustments that could affect patient comfort. The splint was printed using a Phrozen Sonic Mighty 4K 3D printer with SLA technology and E-Guard resin. Post-processing included soaking in isopropyl alcohol to remove unpolymerized residues and careful removal of support structures. Finally, the splints underwent additional polymerization in a high-capacity photopolymerization unit to complete the curing process before clinical use. The photopolymerization unit used for this final step was equipped with a combination of six fluorescent light tubes, three UV-A, and three blue lights, facilitating additional and uniform polymerization of the splint. The last step in preparing the splint for clinical use was a UV disinfection process.

Once the occlusal guard was placed on the patient, various characteristics were evaluated by the researcher. The exception was the taste perception, which was directly assessed by the patient through a survey rating the guard as tasteless, good-tasting, or bad-tasting. To determine any color change, a visual comparison was made by the researcher between the original guard, kept in a sealed glass container, and the guard in use by the patient, classifying them as no color change or with color change.

The retention of the splint was evaluated intraoperatively, checking if it offered resistance to attempts at disinsertion, with possible ratings of with retention or without retention. Adaptability was also determined intraoperatively, examining if the guard properly fitted the dental surfaces, classifying the splints as clinically adaptable or not. Tilting was considered present if, when pressure was applied to the anterior region of the splint in the mouth, a rotational movement was observed that could dislodge it from the opposite region; possible responses were yes or no. The need to repeat the fabrication of the splint in case structural defects prevented its proper placement or delivery to the patient was also observed, with options of yes or no.

Occlusal adjustment was determined using 40-micron articulating paper and a flame-shaped bur in a handpiece, seeking the highest number of contacts possible both in the posterior and anterior sectors to achieve mutually protected occlusion. The adjustment was considered good or bad based on these criteria. The potential for perforation was assessed by direct observation of the guard, with binary outcomes of yes or no. Finally, the number of contact points was evaluated based on the uniformity and symmetry required, where the ideal guard should present equal to or more than 12 occlusal contact points; guards were classified as having fewer than 12 contact points or 12 or more.

After the initial placement and evaluation of the occlusal guards, two subsequent evaluations were scheduled. The first of these took place 10 days after the start of the study, with the objective of making the necessary adjustments to the splints and reevaluating the mentioned variables. This allowed for close monitoring of the treatment's evolution and making the required modifications to optimize the functionality and comfort of the guards.

A third evaluation was then conducted at 60 days. This long-term follow-up is essential to assess the durability and effectiveness of the occlusal splints and to make the final adjustments needed. During this visit, patients received detailed information on how and where to continue their treatment with the occlusal guard within the facilities of the Faculty of Stomatology at the Autonomous University of San Luis Potosí (UASLP), ensuring ongoing care and comprehensive attention.

RESULTS

Organoleptic Properties

Regarding taste, 100% of patients in both groups, in both conventional and digital workflows, reported a tasteless perception in all measurements taken. As for color change, the analog flow splints maintained their original color without chromatic alterations in the three evaluations conducted. However, for digital flow splints, although no changes were observed in the initial measurement or at 10 days, a shift to a yellowish color was detected at 60 days.

Splint Stability

The data in Table 1 indicates that for the analog flow group, 100% retention, adaptability, and absence of tilting were maintained across all time points (basal, 10 days, and 60 days). For the digital flow group, there was a slight initial challenge with one splint showing issues with retention, adaptability, and tilting at the baseline. However, this was resolved by the 10-day mark, and from there, the digital splints matched the analog group in all aspects at 10 and 60 days. Only one digital splint required remaking at the baseline, indicating a need for initial adjustments in the digital workflow. Overall, both workflows showed excellent long-term stability.

Occlusion

The data from Table 2 indicates that occlusal adjustments for both analog and digital flows were successful across all time points, with a 100% success rate (good adjustment) reported. Concerning perforation, no instances were noted in the analog flow group, whereas the digital flow group experienced an increase in perforations over time, with 20% at baseline and 10 days, and 40% at 60 days. In terms of the number of occlusal contacts, the analog flow group started with all splints having more than 12 contacts but dropped to none having that many at 10 and 60 days. In contrast, the digital flow group showed variability, with 40% achieving more than 12 contacts initially but none reaching that number at later evaluations. This suggests that while occlusal adjustment remains stable, the physical integrity of the digital splints, as indicated by perforation, may decrease over time, and maintaining an adequate number of occlusal contacts appears to be a challenge for both types of splints as time progresses.

Table 1. In-mouth stability characteristics

		Analog Flow n=5			Digital Flow n=5		
		Basal	10 Days	60 Days	Basal	10 Days	60 Days
		Frequency (%)					
Retention	With retention	5(100)	5(100)	5(100)	4 (80)	5(100)	5(100)
	Without retention	0(0)	0(0)	0(0)	1(20)	0(0)	0(0)
Adaptability	Adaptable splints	5(100)	5(100)	5(100)	4 (80)	5(100)	5(100)
	Non-adaptable splints	0(0)	0(0)	0(0)	1(20)	0(0)	0(0)
Tilting	No	5(100)	5(100)	5(100)	4 (80)	5(100)	5(100)
	Yes	0(0)	0(0)	0(0)	1(20)	0(0)	0(0)
Splint Repetition	Yes	0(0)	0(0)	0(0)	1(20)	0(0)	0(0)
	No	5(100)	5(100)	5(100)	4 (80)	5(100)	5(100)

Table 2. Occlusal Characteristics

		Analog Flow n=5			Digital Flow n=5		
		Basal	10 Days	60 Days	Basal	10 Days	60 Days
		Frequency (%)					
Occlusal Adjustment	Good	5(100)	5(100)	5(100)	5(100)	5(100)	5(100)
	Bad	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Perforation	Yes	0(0)	0(0)	0(0)	1(20)	1(20)	2(40)
	No	5(100)	5(100)	5(100)	4(80)	4(80)	3(60)
Number of Contacts	≥ 12	5(100)	0(0)	0(0)	2(40)	0(0)	0(0)
	< 12	0(0)	5(100)	5(100)	3(60)	5(100)	5(100)

DISCUSSION

The management of temporomandibular disorders (TMD) encompasses a broad range of modalities due to the multifactorial nature of their origin. These modalities are divided into two main categories: conservative (reversible) and non-conservative (irreversible). Among the conservative options are biofeedback, occlusal splints, physiotherapy, and patient education, which are recommended as the initial approach due to limited evidence in treatments. Splint therapy is considered the gold standard in TMD treatment because of its favorable benefit-risk ratio.[3]

The traditional process of preparing an occlusal splint involves several stages, such as the need for an adjustable articulator, a facebow, and the intervention of a dental technician to manufacture an acrylic splint, which entails multiple clinical appointments. However, digital technology has advanced in dentistry, allowing for the more efficient fabrication of occlusal splints using digital scanners and digital facebows, without the need for a dental technician.
The aim of this research was to establish whether there are differences in the properties of occlusal splints depending on the material and manufacturing method. Such results were obtained through the fabrication of splints using both conventional and digital workflows.

There are several studies evaluating analog and digital splints, but they are mainly in vitro studies. Therefore, studies comparing these two methods in an in vivo environment are limited; thus, it was decided to make this research a pilot study, to identify potential issues in study design, data collection procedures, and methodology before conducting a large-scale study, to refine the protocol as well as logistics and procedures to minimize errors. A pilot study is an essential tool for planning and executing high-quality research, minimizing risks, and maximizing the likelihood of success in the main study.[4]

In this study, several properties of occlusal splints were evaluated including taste, color stability, retention, adaptability, tilting, need for reprinting, and the number of chairside adjustments needed upon delivery, as well as perforations and contact points for both methods. These evaluations were carried out by a single dentist, reducing potential inter-operator differences.

Patients from both digital and analog groups reported the splints as tasteless, contrasting with a previous study where some reported an unpleasant taste with thermocurable splints, possibly due to material handling or the polishing process. No previous information for comparison was found for digital splints.[5]

Color stability was assessed visually; digital splints changed color after 60 days, while thermocured acrylic ones remained unchanged. This supports findings from a 2022 study comparing 3D printed resin samples and their color changes in different aging environments.[6] Another in vitro study in 2023 examined the effect of common beverages on accelerated aging and color stability of resins, revealing significant differences across resin groups.[7] Our study suggests color changes might result from saliva contact, bacteria, dental plaque, and patient cleaning, as well as the printing process itself.

Other desirable occlusal characteristics for a splint to achieve its therapeutic goals include occlusal adjustments, perforations, and the number of contact points. An occlusal splint was considered to have a good fit if it featured canine guidance, anterior guidance, and at least one occlusal contact point per tooth, as is characteristic of a Michigan splint.[8]

This research assessed essential features to maintain the stability of dental guards in the mouth, such as retention, adaptability, tilting, and the need for reprinting. All conventional splints met these criteria, whereas one digital splint had issues with fit and retention, necessitating a successful reprint without an additional appointment. This contrasts with previous studies that suggested digital splints had better retention than traditional ones. Furthermore, such studies highlighted the advantages of digital manufacturing, including the ability to make adjustments and reprints directly in the dental office using intuitive software, which reduces operational costs and simplifies staff training.[9,10]

Initially, 60% of the digital splints had 12 or more contact points, indicating superior initial precision. In contrast, all analog splints had fewer than 12 contact points. However, in subsequent measurements, both digital and analog splints achieved the desired 12 or more contact points. A study in 2023 also assessed occlusal contact precision (canine guidance, anterior guidance, and at least one occlusal contact point per tooth in centric relation) and found digital splint occlusal contact to be significantly better than conventional ones, supporting this study's findings.[9] A study in Barcelona evaluated volumetric changes on the occlusal surface of CAD-CAM occlusal devices following a fully digital workflow after occlusal adjustment compared to those produced analogically. Participants received two occlusal devices, one from each method. Digital workflow splints required significantly fewer occlusal adjustments, confirming the results seen here, where digital splints showed more accurate fitting in the baseline measurement.[11]

Regarding perforations, one guard was printed with perforations, anticipated due to the patient's occlusion characteristics. Later, another guard was perforated during occlusal adjustment. An in vitro study examined the wear of nine materials, including PMMA, for splints produced conventionally, milled, and printed. PMMA-based splint materials showed uniform wear resistance, while CAD-CAM milled polycarbonate and additive manufacturing materials for flexible splints, except for KeySplint Soft, showed greater wear. This may be due to the layers deposited parallel to the load direction and layer adhesion. However, KeySplint Soft material, similar in composition to that used in this study, confirmed similar wear resistance to PMMA-produced splints.[12] Based on our experience, resin materials exhibit notable strength and hardness. Nevertheless, patient-specific needs led to molar region corrections, reducing the splint's planned thickness, possibly explaining the perforations observed, as the reduced thickness could affect the material's integrity in those areas.

Regarding costs, adopting a fully digital process entails significant initial investment in expensive software and hardware. However, once this initial investment is made, the cost of printing splints is more economical compared to conventional methods.[13]

The enhanced efficiency of digital dentistry workflows allows dental technicians to allocate more time to other tasks, improving productivity and profitability. The digital splint manufacturing process is notably dynamic, making it faster and more cost-effective than traditional methods. The feasibility relies on the dentist's digital training, which may require substantial initial investment but significantly reduces patient treatment time.[14]

3D printing is a pivotal element in dentistry's evolution, underscoring the need for dentists to acquire related skills to effectively integrate this technology into their practice. The current generation of dental professionals, already well-versed in digital dentistry, is prepared to invest in this field. This digital approach also enhances patient experience by enabling the visualization of anticipated results through Computer-Aided Design (CAD) solutions. Utilizing digital dental tools for patient treatment monitoring opens avenues for collaborative workflows and knowledge sharing via social media, playing a significant role in the healthcare industry.[15]

It's important to note that the majority of research has been centered on in vitro studies, making the contribution of in vivo studies particularly valuable. This in vivo study confirmed and offered a more applied perspective on different workflows and materials used, enhancing the clinical relevance of the findings. This method is expected to be a key component of a future clinical study with a larger patient population.[16]

CONCLUSION

Analog and digital splints perform effectively over a 60-day period, with high retention and adaptability rates. Digital splints displayed superior initial contact point precision and required fewer occlusal adjustments, though they experienced a higher rate of perforation over time. Ultimately, both splint types achieved the goal of maintaining stability and occlusal function in the mouth.

REFERENCES

1. Albagieh H, Alomran I, Binakresh A, Alhatarisha N, Almeteb M, Khalaf Y, et al. Occlusal splints-types and effectiveness in temporomandibular disorder management. Saudi Dent J. 2023;35(1):70-9. Doi: https://doi.org/10.1016/j.sdentj.2022.12.013

2. Loupes OIE, Fill KIV. Digital Workflow for Occlusal Guards Digital technologies that allow the in-office design and fabrication of occlusal guards can reduce chairtime and fabrication time, thus improving the patient and provider experience.

3. Gary M, Quek SY, Khan J. The relation of temporomandibular disorders and dental occlusion: a narrative review. Quintessence Int. 2022;53(5):450-9.

4. Lackey NR, Wingate AL. The pilot study: One key. Adv Des Nurs Res. 1997;375. Doi: https://doi.org/10.4135/9781452204840.n15

5. Nekora A, Evlioglu G, Ceyhan A, Keskin H, Issever H. Patient responses to vacuum formed splints compared to heat cured acrylic splints: pilot study. J Maxillofac Oral Surg. 2009;8:31-3. Doi: https://doi.org/10.1007/s12663-009-0008-9

6. Lee EH, Ahn JS, Lim YJ, Kwon HB, Kim MJ. Effect of layer thickness and printing orientation on the color stability and stainability of a 3D-printed resin material. J Prosthet Dent. 2022;127(5):784-e1. Doi: https://doi.org/10.1016/j.prosdent.2022.01.024

7. Wallach R, English JD, Moon A, Brock RA, Paravina RD, Kasper FK. Colour stability of 3D-Printed orthodontic brackets using filled resins. Orthodontics & Craniofacial Research. 2023 Dec;26:180-7. Doi: https://doi.org/10.1111/ocr.12665

8. Badel T, Simonić-Kocijan S, Lajnert V, Dulčić N, Zadravec D. Michigan splint and treatment of temporomandibular joint. Med Flum. 2013;49(2):112-20.

9. Lin R, Yan YQ, Sun J, Yu CH. A Comparison of the Accuracy Between a Digital Fabrication Workflow and a Conventional Fabrication Workflow for Occlusal Appliances: A Pilot Study. Int J Prosthodont. 2023;36(4). Doi: https://doi.org/10.11607/ijp.7947

10. Wesemann C, Spies BC, Schaefer D, Adali U, Beuer F, Pieralli S. Accuracy and its impact on fit of injection molded, milled and additively manufactured occlusal splints. J Mech Behav Biomed Mater. 2021;114:104179. Doi: https://doi.org/10.1016/j.jmbbm.2020.104179

11. Blasi A, Henarejos-Domingo V, Palacios-Bañuelos R, Vidal-Ponsoda C, Aparicio C, Roig M. CAD-CAM and analog occlusal splints comparison based on the amount of occlusal adjustments. 3D analysis of the volumetric changes: A pilot study. J Esthet Restor Dent. 2023;35(8):1271-8. Doi: https://doi.org/10.1111/jerd.13080

12. Gibreel M, Perea-Lowery L, Vallittu PK, Garoushi S, Lassila L. Two-body wear and surface hardness of occlusal splint materials. Dent Mater J. 2022;41(6):916-22. Doi: https://doi.org/10.4012/dmj.2022-100

13. Tallarico M. Computerization and digital workflow in medicine: Focus on digital dentistry. Materials. 2020;13(9):2172. Doi: https://doi.org/10.3390/ma13092172

14. Jahangiri L, Akiva G, Lakhia S, Turkyilmaz I. Understanding the complexities of digital dentistry integration in high-volume dental institutions. Br Dent J. 2020;229(3):166-8. Doi: https://doi.org/10.1038/s41415-020-1928-5

15. Bessadet M, Drancourt N, El Osta N. Time efficiency and cost analysis between digital and conventional workflows for the fabrication of fixed dental prostheses: A systematic review. The Journal of Prosthetic Dentistry. 2025 Jan 1;133(1):71-84. Doi: https://doi.org/10.1016/j.prosdent.2024.01.003

16. Perea-Lowery L, Gibreel M, Garoushi S, Vallittu P, Lassila L. Evaluation of flexible three-dimensionally printed occlusal splint materials: An in vitro study. Dent Mater. 2023;39(10):957-63. Doi: https://doi.org/10.1016/j.dental.2023.08.178