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# Pilot clinical comparison of three occlusal splint fabrication techniques: A preliminary study

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**To compare laboratory production time, clinical adjustment time, and patient-reported comfort of three occlusal splint fabrication techniques (heat-cured acrylic, vacuum-adapted acrylic, and CAD-CAM 3D-printed splints) in a pilot feasibility study. Three participants each received three splints, one fabricated with each technique. Laboratory production time, chairside adjustment time, and comfort (VAS) were recorded. Vacuum-adapted splints required the shortest laboratory production time (mean = 92 min, SD = 25.35). Heat-cured splints required longer processing (mean = 114 min, SD = 6.08). The CAD-CAM splints showed the longest total workflow duration (mean = 133 min, SD = 6.08), although they required less manual technician work. Intraoral adjustment times were similar between heat-cured and vacuum-adapted splints (means = 28 min and 26.66 min, respectively). None of the CAD-CAM splints seated fully at delivery, preventing proper adjustment. Vacuum-adapted splints received the highest comfort scores. Within the limitations of this pilot study with three participants, vacuum-adapted and heat-cured splints showed clinically acceptable performance and comparable adjustment times. CAD-CAM splints reduced manual workload but suffered from significant seating and fit issues, indicating the need for workflow refinement before clinical implementation. Even as splint fabrication is moving towards a more digital workflow, the old methods, especially vacuum-adapted splints, continue to deliver timely and comfortable results to patients. Further studies with more participants need to be done so that there can be a clear digital splint fabrication workflow.**

**Keywords** CAD-CAM dentistry, Heat-cured acrylic splints, Occlusal splints, Patient comfort, Splint fabrication techniques, Temporomandibular disorders (TMDs), Vacuum-adapted splints

Temporomandibular disorders (TMDs) are highly prevalent conditions, with signs or symptoms reported in 60–70% of the general population[1,2]. They represent the second most common musculoskeletal pain disorder after chronic low back pain and are a major source of chronic orofacial discomfort. Typical manifestations include joint noises, pain during mandibular function, limitations or deviations in mandibular movement, headaches, and compensatory postural adaptations of the head and neck[3].

Since occlusal splints were first introduced in 1901, numerous designs and materials have been developed in parallel with evolving concepts for managing bruxism and TMDs[4]. Occlusal splints are defined as rigid, removable appliances that cover the full occlusal and incisal surfaces of the maxillary arch[5]. A wide range of configurations has been described—including soft splints, anterior repositioning appliances, neuromuscular devices, mandibular repositioning appliances, pivot splints, relaxation splints, and stabilization (Michigan-type) splints[4,6]. Among these, the chin-point-guided centric relation maxillary stabilization splint remains the most extensively documented and commonly used option for TMD management.

Stabilization splints aim to mitigate the consequences of parafunctional activities such as occlusal wear, attrition, and dentinal hypersensitivity[3,7,8]. Their clinical effectiveness depends on achieving bilateral and simultaneous contacts in maximum intercuspal position (MIP), along with immediate canine-guided disocclusion during mandibular excursions[5,9]. When these criteria are not met, splints may introduce new occlusal interferences or exacerbate muscle dysfunction[10].

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Splint fabrication methods vary considerably. Conventional techniques include acrylic dough application, heat-curing processes, and vacuum-adapted thermoplastic sheets[11]. Although dimensional stability and minimal distortion are essential for clinical success, current evidence does not identify any technique as definitively superior[11,12].

Digital workflows have gained increasing relevance, and some authors predict that traditional cast-based methods may ultimately be replaced by computer-assisted fabrication. Digitally produced splints have demonstrated promising levels of accuracy and similar clinical performance[13–15]. Nevertheless, there is still insufficient justification to abandon conventional impression techniques unless digital alternatives clearly outperform them[16].

Although vacuum-formed splints are often considered faster and easier to fabricate, fit, and deliver[10], the current evidence does not consistently demonstrate superiority of any method for clinicians, technicians, or patients. Consequently, fabrication technique selection frequently depends on clinical experience, individual training, and laboratory preference[17].

## Applications of occlusal splints

*Management of parafunctional activities*

Occlusal splints help reduce the mechanical effects of clenching and grinding, thereby lowering muscular overload and myofascial pain[2,12,18,19].

*Protection of soft tissues*

They prevent involuntary biting of cheeks and lips, minimizing soft-tissue trauma[7,20].

*Reduction of periodontal trauma*

By redistributing occlusal forces, splints lessen traumatic loading on periodontal structures, supporting periodontal stability[10,20].

*Protection of restorations and implants*

Splints reduce occlusal stress on restorative materials, compromised teeth, and implants, lowering the risk of mechanical overload or fracture[9,12].

*Restoration of vertical dimension*

They allow temporary increases in vertical dimension during full-mouth rehabilitation, facilitating diagnostic and therapeutic procedures[5,12].

*Prevention of Porcelain-Induced wear*

Splints help minimize enamel wear against opposing porcelain restorations, protecting natural dentition[9].

*Assessment of Bruxism patterns*

Splints provide a diagnostic surface to evaluate occlusal wear patterns and guide treatment decisions, offering a simple and informative monitoring tool[19].

## Purpose

This study presents findings from an investigation into the fabrication and adjustment of occlusal splints, aiming to identify the most comfortable splint design preferred by patients, the least time-consuming method for clinicians and technicians, and the most reproducible technique in terms of reported clinical outcomes. Specifically, the research seeks to identify potential methodological flaws in current fabrication protocols and provide preliminary data to support sample size calculations for future clinical trials.

Three widely used fabrication techniques were compared: Poured heat-cured acrylic splints, considered the gold standard due to their long-standing clinical use and dimensional stability[11,21]. Vacuum-adapted splints with acrylic dough application, offering faster production and delivery, though sometimes criticized for limited precision in fit and durability[10,16]. CAD-CAM (Computer-Aided Design and Manufacturing) 3D-printed splints, representing modern digital workflows with potential advantages in reproducibility, accuracy, and reduced manual labor, though concerns remain regarding cost-effectiveness and patient preference[13,15].

This study is timely, given the high prevalence of temporomandibular disorders (TMDs) and sleep bruxism in the population—conditions commonly treated using conservative, reversible interventions such as occlusal splints[2,8,22]. Despite widespread use, there is still no consensus on the most effective splint fabrication and adjustment technique, with preferences often based on clinical experience rather than scientific evidence[12,17]. By directly comparing traditional, vacuum-adapted, and CAD-CAM workflows, this pilot study aims to build confidence in technique selection criteria that enhance patient outcomes, reduce chairside time, and improve laboratory efficiency.

## Design

This investigation used a randomized clinical trial (RCT) design with an intra-subject crossover format to compare three occlusal splint fabrication and adjustment techniques. RCTs are considered the gold standard for evaluating treatment efficacy due to their ability to reduce selection bias and enhance internal validity[23]. An intra-subject design minimizes variability caused by individual differences in occlusal anatomy, bruxism intensity, or TMD symptoms, as each participant serves as their own control—thereby strengthening the study's power and enhancing the credibility of results even with a small sample size[24].

This pilot study represents the initial phase of a larger RCT initially designed to include twelve participants, each receiving all three splint types in randomized order. Due to limited funding and restricted laboratory access, only the pilot phase with three participants was completed. The present manuscript reports on this feasibility phase, which allowed the standardization of procedures, validation of reproducibility, and estimation of clinical and laboratory times prior to full-scale implementation[10,22,25].

Three participants were randomly assigned to receive splints fabricated using each of the three techniques—poured heat-cured, vacuum-adapted with acrylic application, and CAD-CAM printed—administered in a randomized sequence to reduce bias from adaptation or fatigue. Randomization and allocation concealment are best practices in dental research to ensure scientific rigor and reproducibility[25].

This type of intra-subject crossover design has been widely applied in occlusal splint and TMD studies, allowing for direct comparison of comfort, fit, and clinical performance without the confounding effects of inter-patient variability[26,27]. Given the considerable variability in splint fabrication techniques and the lack of consensus on their relative merits, this design is particularly well suited to generating clinically meaningful insights[10,22].

## Methods and materials

All procedures followed a standardized protocol. A sample of three young adult females with an average age of 23 years was selected. The inclusion criteria were[1]: normal or physiologic occlusion[2], absence of signs or symptoms of temporomandibular disorders (TMD), including no muscle tenderness or parafunctional activities[3], no evidence of periodontal disease, and[4] no administration of anxiolytic medication or involvement in habits that activate the nervous system, such as smoking and/or excessive caffeine consumption. These inclusion/exclusion criteria are similar to those used in previous clinical studies evaluating splint therapy in healthy patients[1,2]. All participants were tested with three different types of occlusal splints, each delivered on separate days. The use of occlusal splint therapy has been popular as a treatment concept for TMD, bruxism, and other occlusal dysfunctions[7,8,22]. During the study, we recorded the time required to fabricate each splint and documented any potential shortcomings or disadvantages. Patient comfort was evaluated at the moment of delivery using a Visual Analogue Scale (VAS), which is a well-known measurement tool commonly applied in TMD studies[3,28].

### Splint build process

Design of each splint was performed in line with a standard procedure:

### Impression taking

Impression Taking Dental impressions were taken using irreversible hydrocolloid, ensuring that they were free of bubbles and fine air entrapment[16]. Both the maxillary and mandibular impressions were obtained following the manufacturer's instructions to achieve optimal viscosity and accuracy. Rapid removal was performed to minimize distortion. Proper impression-taking is one of the key steps in splint fabrication[29,30].

### It was a bit confusing Atax Bancor registration

There was some initial confusion related to the bite registration process. Bite Registration To articulate the cast models, a wax bite registration was obtained. A minimum of three wax layers was used to approximate the desired splint thickness in accordance with established recommendations[9]. A hard wax (Moyco®) was softened and molded to the maxillary arch, then pressed until the cusp imprints of the mandibular teeth became visible. The wax registration was verified once chilled. This step is essential for establishing the correct occlusal relationship and achieving accurate splint adjustment[4,11].

### Fabrication and adjustment of splint

All the splints were manufactured based on the currently accepted techniques presented in the previous works[13–15]. The three splints varieties varied in their thickness and material content, known to affect the patient tolerance and muscle activity[5,12,19]. Proper seating and retention were confirmed.

### Comparison of patient comfort

A VAS was used to assess each patient's perception of comfort at the time of splint delivery. Evaluating patient comfort is essential, as consistent splint use depends on both efficacy and wearability[17,31].

### Rationale and reliability

The methodology selected aligns with previous research evaluating the therapeutic benefits of occlusal splints in bruxism and TMD[10,20]. The small sample size reflects the pilot nature of this study, which is common in exploratory trials in occlusal therapy[6,18]. Additionally, recording both the fabrication time and patient comfort provides a comprehensive assessment of clinical viability, an increasingly emphasized factor in splint-related research[4,30].

An arbitrary facebow was used to record the maxillary arch, allowing the corresponding cast to be mounted on a semi-adjustable articulator (Fig. 1). It is important to avoid hand articulation, as it typically introduces inaccuracies and increases the need for chairside adjustments of the device[32,33]. In contrast, such adjustments are generally unnecessary when working with a splint fabricated using CAD-CAM technology, as one of the key advantages of the digital workflow is the precise transfer of occlusal relationships[34]. To prepare the casts from the impressions, a type IV hard natural stone (Kimberlit®) was used. The stone powder and water were mixed according to the manufacturer's instructions, and the mixture was vigorously inserted into the impressions to minimize air entrapment. After twenty-five minutes, the cast was separated from the impression material while still supported by the dental stone[35,36]. The same maxillary and mandibular dental casts were used across all


**Fig. 1**. Wax bite records in MIP for each of the subjects

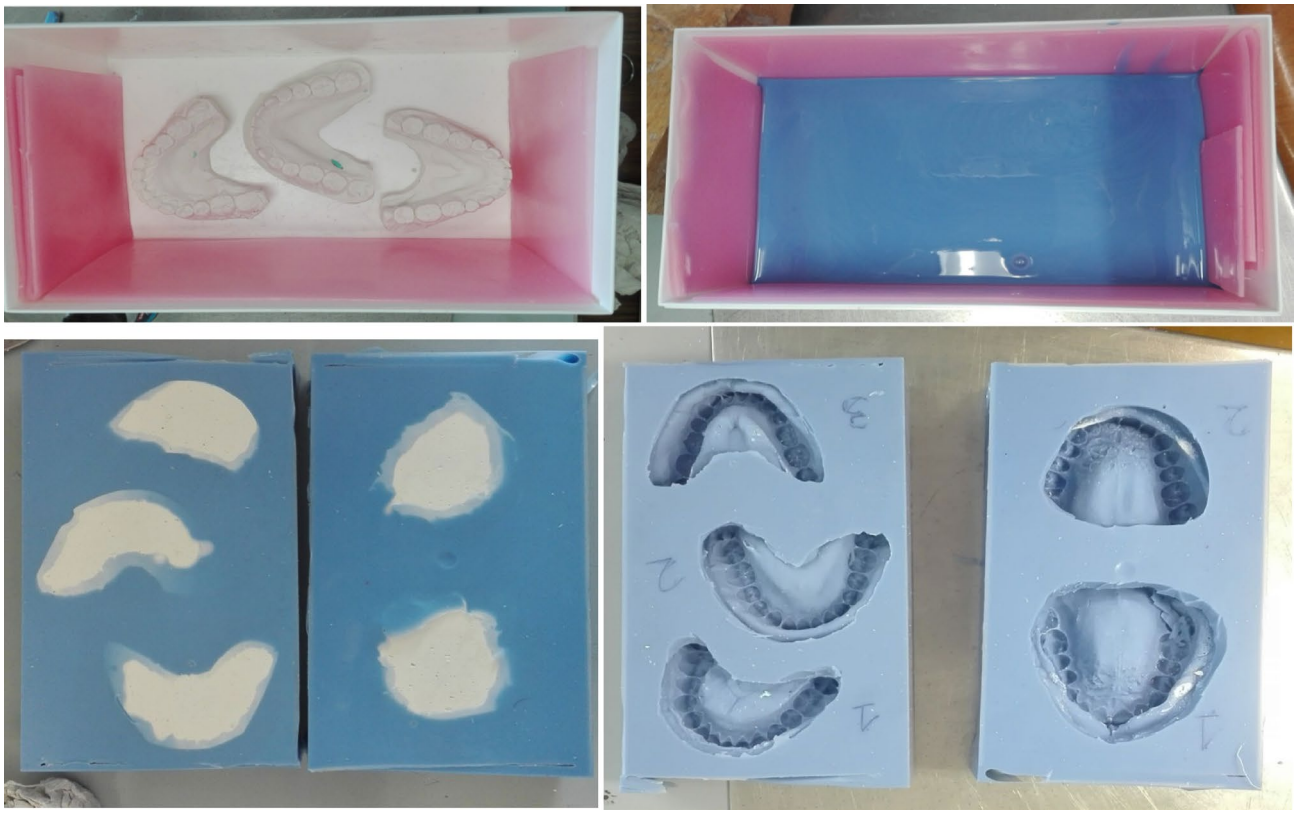

**Fig. 2**. Process of dental casts' silicone impression and final impression for cast duplication

three fabrication methods to control for inter-subject variability. This was ensured by duplicating each cast with a high-precision duplicating silicone (Dupliflex®) (Fig. 2), which allowed the production of as many replicas as required[37,38]. The silicone impressions enabled the creation of multiple identical casts for each subject, thereby controlling variability between methods[39].

## Poured Heat-Cured acrylic Splint — Fabrication steps

*Mounting of casts on articulator*

The maxillary cast was mounted using the facebow record, maintaining the split-cast system for accurate repositioning[32,33] (Fig. 3). The mandibular cast was mounted using the MIP wax record with the incisal pin at 0 mm to preserve the vertical dimension.

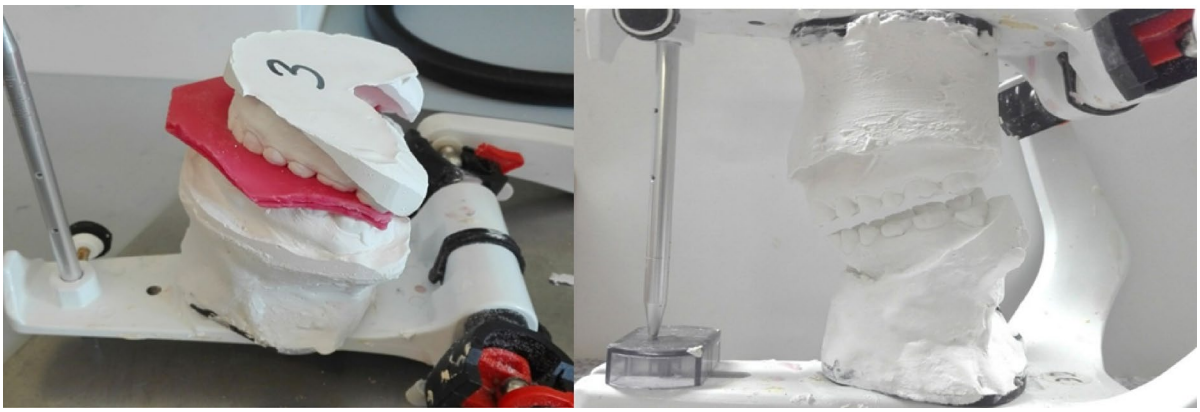

**Fig. 3**. Split-cast on maxillary cast. Mounting of the maxillary cast on articulator following the facialbow record. Mounting of the inferior cast following the MIP bite wax.Final casts mounted with incisal guide pin at 0 mm. We observe the occlusal space created for the splint

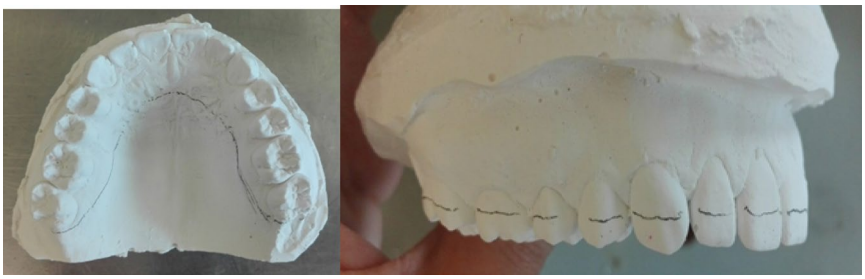

**Fig. 4**. Pencil outline of the splint on the superior cast

*Peripheral border marking*
The outline of the splint borders was drawn on the maxillary cast following the design principles of a Michigan-type stabilization splint[35] (Fig. 4).

*Initial wax base adaptation*
Separating medium was applied, and warmed baseplate wax was adapted over the maxillary arch, extending to all borders and maintaining proper thickness[33,35].

*Occlusal wax-up on articulator*
The articulator was closed to mark cusp indentations. Wax was selectively added or trimmed to achieve bilateral and simultaneous MIP contacts verified with blue articulation ribbon[37].

*Excursive movement adjustment*
Red ribbon was used to evaluate working and balancing contacts. Interferences were selectively removed to establish proper canine guidance and eliminate posterior contacts during lateral and protrusive movements[34,38].

*Final shaping of the wax pattern*
Borders were refined, surfaces smoothed, and sprues were added in distal areas to serve as resin entry canals during processing[39] (Fig. 5).

*Silicone impression of the wax pattern*
A condensation silicone (Zetalabor®) impression of the wax model was taken, reference marks were added, and all wax residues were removed to obtain a clean negative mold[33,35] (Fig. 6A–B).

*Block-out of cast undercuts*
Undercuts were identified and blocked out with wax to prevent acrylic locking and ensure seating comfort[23,37] (Fig. 7).

*Mold reassembly and sealing*
Parting medium was applied to the cast. The silicone mold was repositioned and sealed with wax or cyanoacrylate to prevent leakage during acrylic pouring.

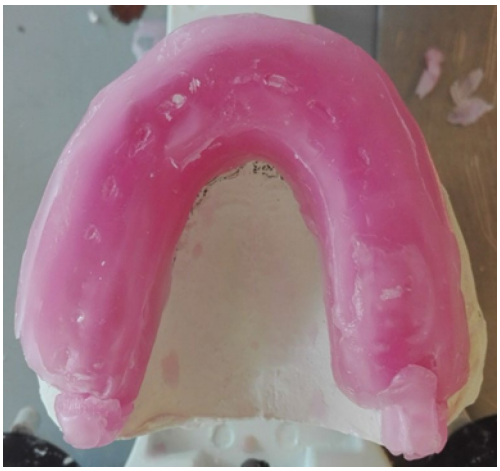

**Fig. 5**. Wax model of the occlusal splint before silicone impression

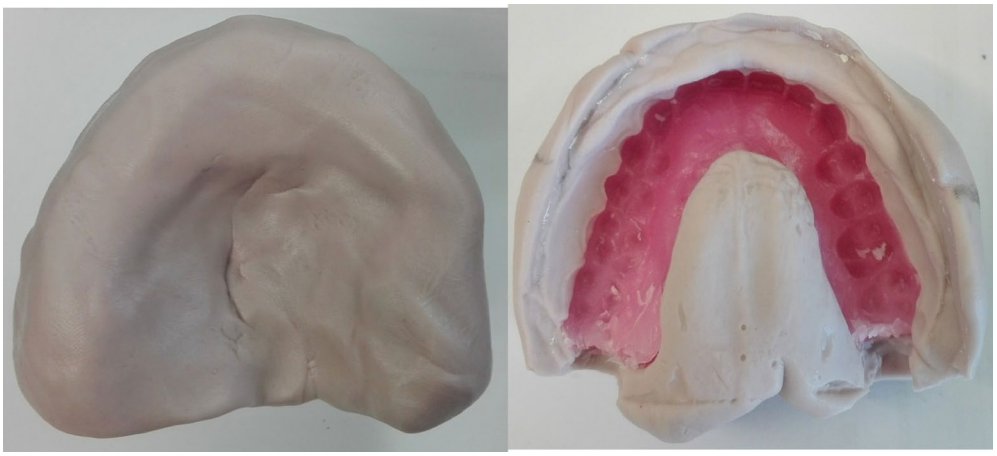

**Fig. 6**. Silicone impression. Withdrawing of the silicone impression

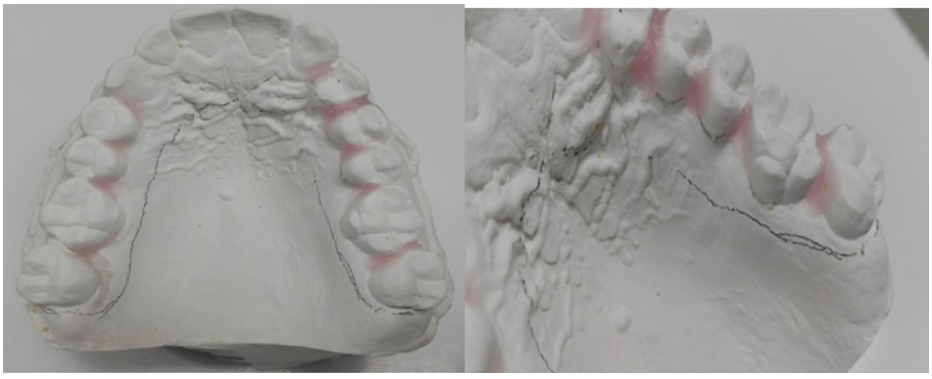

**Fig. 7**. Maxillary cast with blocked deep undercuts

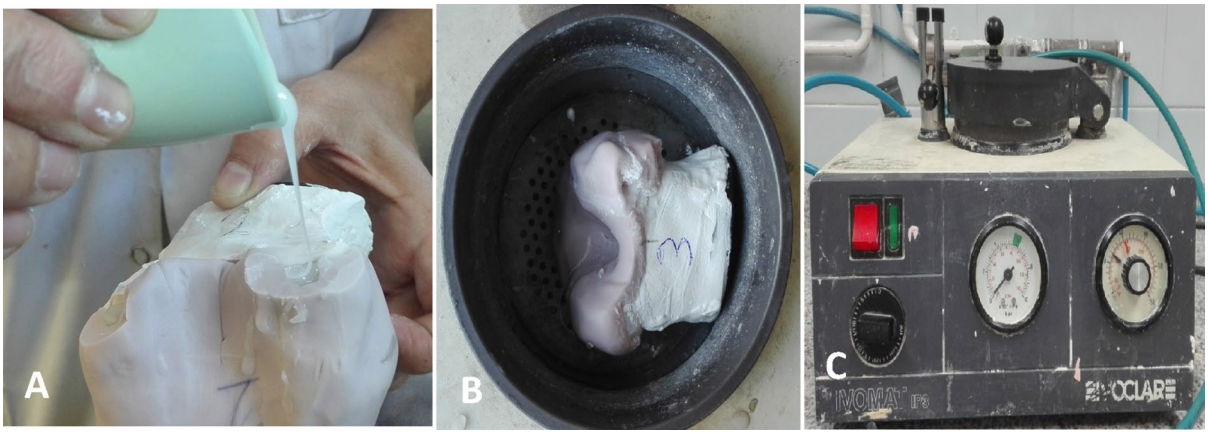


**Fig. 8**. (**A**) Pouring of the acrylic into the silicone impression. (**B**) Cast in the heat and pressure machine. (**C**) Heat and pressure Ivomat machine

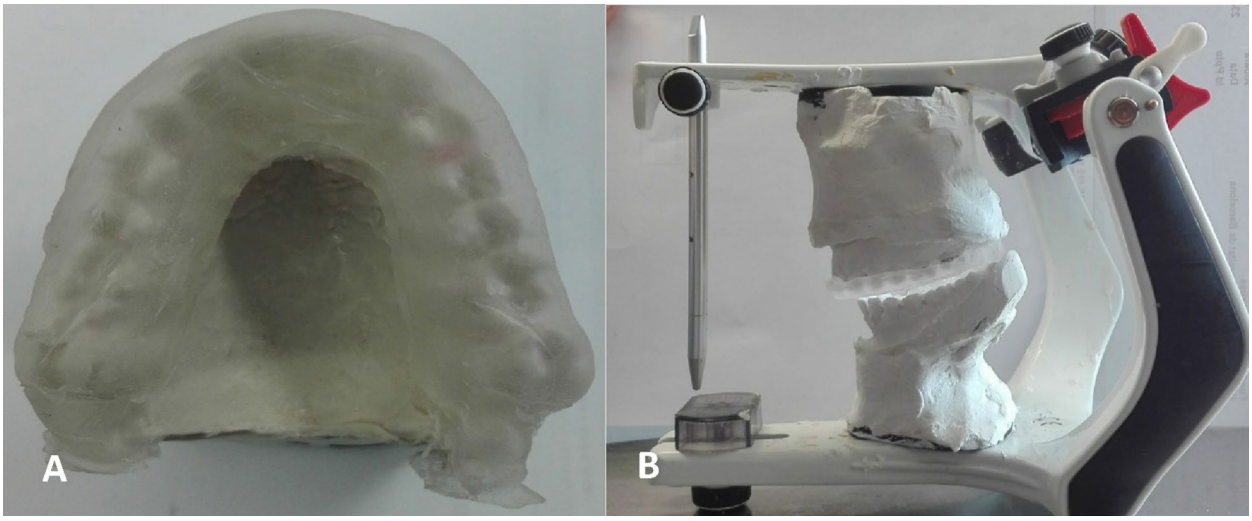


**Fig. 9**. (**A**) Cured acrylic splint. (**B**) Maxillary cast with acrylic splint mounted on the articulator

*Acrylic resin pouring*
Self-curing acrylic resin (Palapress Vario®) was mixed per manufacturer instructions and slowly injected into the sprue canal until overflow occurred at the exit canal, ensuring complete filling.

*Heat and pressure polymerization*
The entire assembly was placed in the Ivomat® unit at 45 °C and 2 bar pressure for approximately 10 min to obtain optimal polymerization and dimensional stability[34,37] (Fig. 8A–C).

*Removal of silicone mold*
The silicone was peeled off carefully, leaving the acrylic splint fixed on the cast (Fig. 9A).

*Remounting on articulator*
The cast with the curing splint was returned to its mounted position to verify occlusal accuracy under simulated functional loading[33,39] (Fig. 9B).

*Occlusal adjustments*
Blue articulating ribbon was used for MIP contacts, and red ribbon for excursive movements. Premature and heavy contacts were removed using a carbide bur following established splint adjustment protocols[4,9] (Fig. 10).

*Internal corrections*
After removal from the cast, the intaglio surface was checked for excess acrylic, interfering retentive zones, and sharp edges. These areas were corrected to improve comfort and reduce mucosal irritation[2,8].

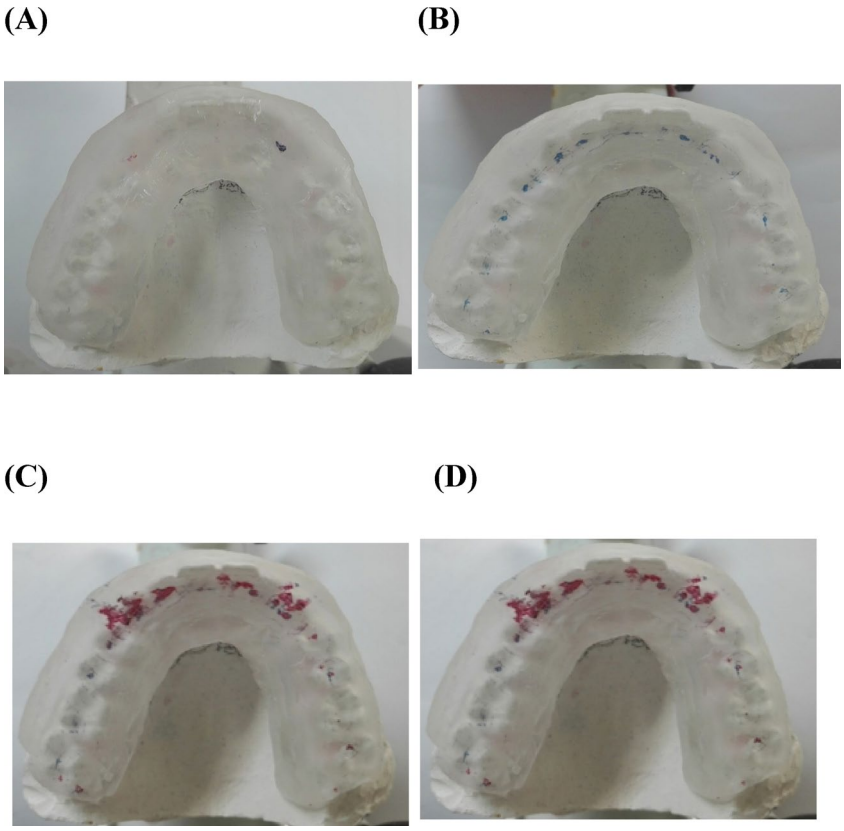


**Fig. 10**. Occlusal adjustment on the articulator. **A** and **B**. Before and after MIP contacts shown with blue ribbon. **C** and **D**. Before and after excursive contacts shown with red ribbon

**Fig. 11**. Polishing procedures of the occlusal splint.Brush with calcium carbonate powder for polishing. Goat hair brush and pumice powder for giving shine. Polishing machine. The figure has been replaced with a higher-resolution version to improve clarity, as requested by the reviewers

*Border refinement*
Peripheral contours were smoothed to enhance stability and retention.

*Final Polishing*
The splint was polished with calcium carbonate, pumice, and a goat-hair brush to obtain a smooth, glossy surface and improve patient comfort[18,30] (Fig. 11).

## Vacuum-Adapted acrylic Splint — Fabrication steps

*Articulator mounting*
The maxillary cast was mounted using a facebow transfer and the mandibular cast using the MIP wax record, ensuring accurate maxillomandibular positioning[10,29] (Fig. 3).


**Fig. 12**. (**A**) Cast placed on the vacuum forming machine Biomat. (**B**) Plastic vacuum adapted over the maxillary cast

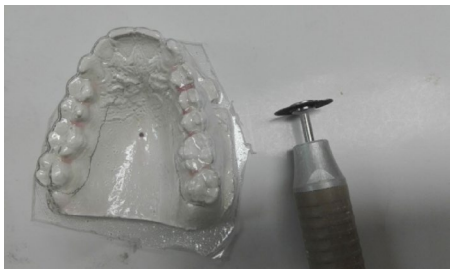

**Fig. 13**. Cutting of excess vacuum with disc and dental handpiece

*Peripheral border marking*
The extension of the splint was outlined on the maxillary cast following stabilization splint design principles (Fig. 4).

*Block-out of undercuts*
Deep undercuts and retentive regions were blocked with wax to avoid acrylic locking and ensure proper seating[4,6] (Fig. 7).

*Vacuum adaptation of thermoplastic sheet*
A 1 mm transparent, hard-elastic plate (Ortoteam®) was heated and adapted onto the cast using the Biomat® vacuum-forming machine, achieving full adaptation over the arch[13,14] (Fig. 12A–B).

*Initial trimming of vacuum-formed base*
Excess material was removed with a disc on a dental handpiece, following the previously established borders to prevent soft-tissue irritation[4,9] (Fig. 13).

*Articulator positioning*
The vacuum-adapted sheet was re-seated on the maxillary cast and mounted on the articulator to verify occlusal clearance.

*Acrylic application over vacuum base*
Self-curing acrylic resin (Palapress Vario®) was mixed until a doughy consistency was achieved. – The mandibular cast was coated with Vaseline to prevent adhesion. – The vacuum surface was lightly treated with monomer to enhance bonding. Resin was applied over the vacuum shell and indented by closing the articulator to register mandibular cusp tips[5,15] (Fig. 14).

*Manual shaping of occlusal contacts*
Using a monomer-moistened finger, the occlusal surface was smoothed and adjusted. Additional resin was applied as needed to achieve complete contacts and proper canine guidance[3,28].

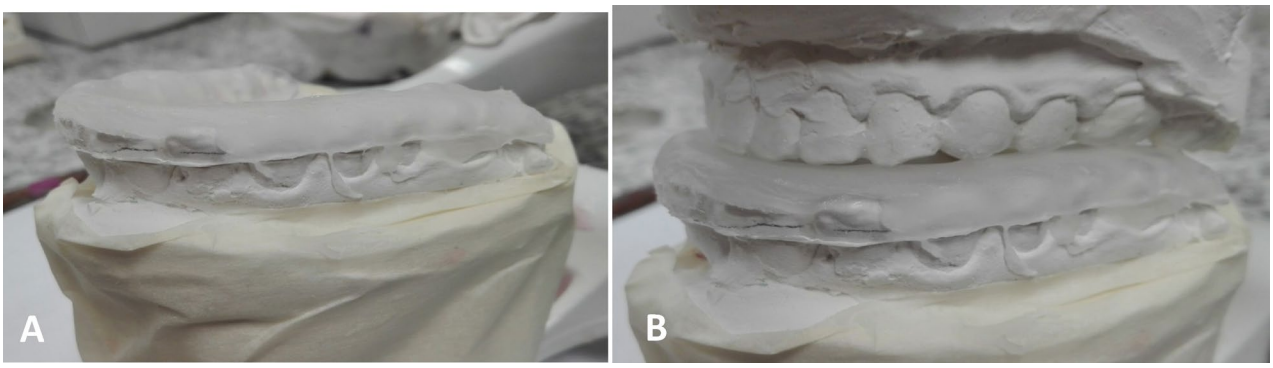


**Fig. 14**. Dough application of the acrylic over the vacuum. (**A**) Acrylic over the vacuum. (**B**) Testing of occlusal contacts of mandibular teeth over the acrylic

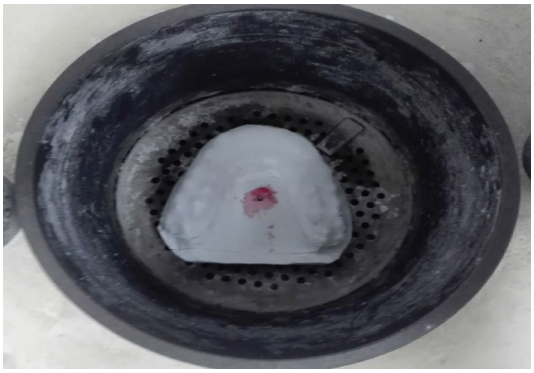

**Fig. 15**. Cast with acrylic resin in the heat and pressure machine (Ivomat) for curing

*Removal of excess acrylic. Pressure-curing polymerization*
Buccal and palatal excess acrylic was carefully trimmed with a scalpel to refine the contours.The cast with the splint was placed in the Ivomat® curing machine at 45 °C and 2 bar for 7 min to complete polymerization[14,21] (Fig. 15).

*Occlusal verification and refinement*
Blue articulating ribbon was used to verify MIP contacts and red ribbon for excursive movements. Premature contacts were removed using a resin bur following standard splint adjustment protocols[4,9].

*Internal finishing. Final Polishing*
The intaglio surface was examined and corrected for any acrylic excess or retentive zones that could irritate the mucosa. External and internal surfaces were polished following the same protocol described for the poured acrylic splint, using calcium carbonate, pumice and a goat-hair brush[18,30] (Figs. 11 and 12).

## CAD-CAM (3D Printed) Splint – Fabrication steps

*Cast Preparation in MIP*
Maxillary and mandibular casts were positioned in maximum intercuspal relationship (MIP) using the wax record obtained clinically. This ensured that all splints were fabricated from identical interarch relationships[14,29] (Fig. 16).

*MIP scan acquisition*
Both casts were placed together on the scanning platform, and an initial scan was taken to capture their spatial relationship in MIP[14,29] (Fig. 17).

*Individual arch scanning*
Each cast was then scanned individually. The digital rotation functions of the scanner software allowed complete capture of all anatomical surfaces[14,29] (Fig. 18).

*Digital triangulation and model alignment*
The individual maxillary scan was aligned with the MIP scan, generating a final combined model accurately representing both arches in MIP[14,29] (Fig. 19A–B).


**Fig. 16**. Dental casts with bite registration prepared for scanning

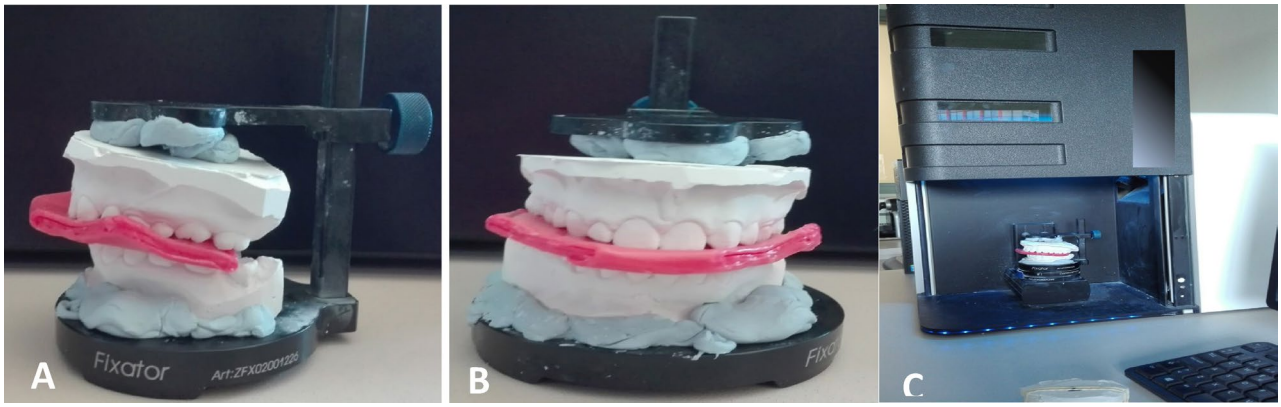


**Fig. 17**. **A** and **B**. Dental casts on platforms for 3D scanning. **C**. Dental casts placed in 3D scanner

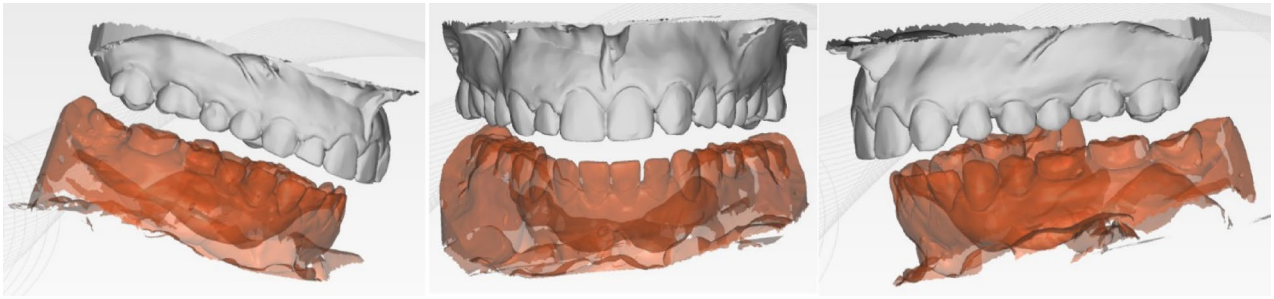

**Fig. 18**. Dental casts scanned

*Importing files into CAD software*
Scans were exported in.stl format and imported into the Exocad® CAD program for splint design[13,15].

*Peripheral border definition*
The splint's outer borders were digitally traced on the maxillary arch to define its extension and ensure proper adaptation[13,15] (Fig. 20).

*Virtual splint construction*
The software generated the initial 3D splint model with adjustable thickness for both occlusal and peripheral surfaces.

*Occlusal refinement using the digital contact plane*
Material was removed or added virtually until balanced, bilateral MIP contacts were achieved.
The occlusal design was verified using digital articulating maps in the software[13,15] (Fig. 21).

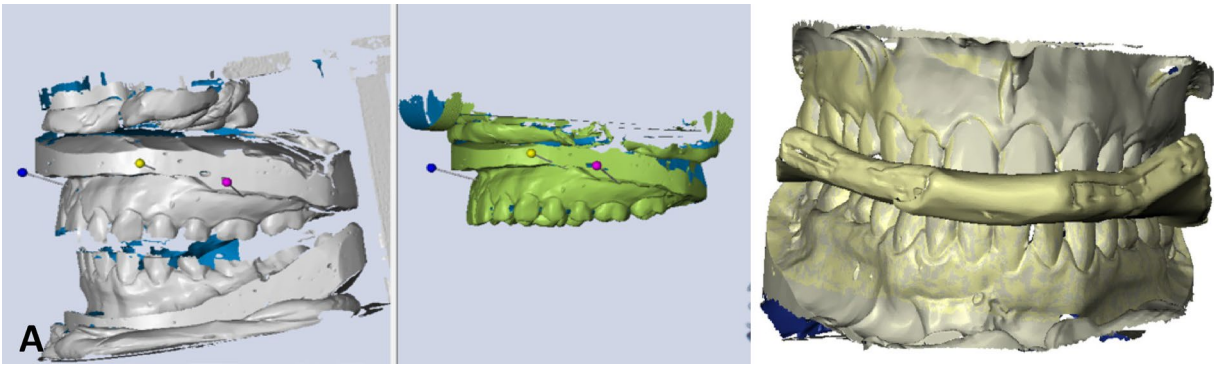


**Fig. 19**. (**A**) Triangulation of the superior cast from the maxillary scan to the MIP scan. (**B**) Final scan of casts in MIP

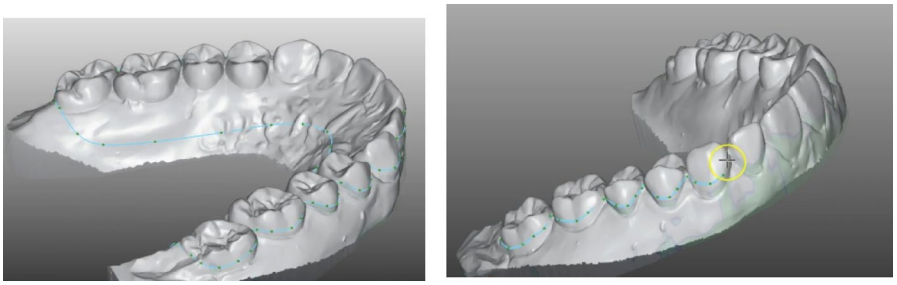

**Fig. 20**. Outlining of the peripheral borders of the splint

*Excursive adjustment*
Working and balancing contacts were digitally corrected to create appropriate canine guidance and eliminate posterior excursive contacts.

*Final digital smoothing*
Borders and surfaces were smoothed using CAD tools to enhance comfort and splint adaptation.

*Exporting the.stl file*
The final splint design was exported as an.stl file for 3D printing[13,29] (Fig. 22).

*3D printing of the splint*
The splint was printed using a Formlabs Form 2® 3D printer with light-curing resin, following manufacturer parameters for layer thickness, orientation, and support structures (13,14,29) (Fig. 23).

*Post-processing and finishing*
Support structures were removed (Fig. 24). The splint was cleaned, cured, and polished following the same finishing procedure used for conventional acrylic splints[18,30] (Figs. 11 and 12).

## Intra oral delivery and equilibration of the processed occlusal splint

The same procedure was followed for all three types of splints. During the try-in appointment, the first step was to ensure that the splint fitted properly over the maxillary teeth. Before beginning occlusal equilibration, the splint had to be fully and passively seated. Patients were then asked to place the splint themselves to assess comfort and stability. Any irregularities on the proximal surfaces or excessive retention on the buccal surfaces that could interfere with complete seating were identified and adjusted. Excess material was carefully trimmed using a slow-speed carbide bur until a clinically acceptable fit[17,31].

Adjustments to the occlusion were made with the patient in a reclined position. Maximum intercuspal position (MIP) contacts and excursive contacts were identified using blue and red articulating ribbons, respectively. Mandibular MIP functional cusp tip and incisal edge contacts were marked with blue ribbon. Premature or heavy contacts were selectively reduced with a pear-shaped carbide bur until simultaneous bilateral MIP contacts were achieved[2,22]. Red ribbon was used to identify excursive contacts by instructing the patient to perform lateral and protrusive movements. All laterotrusive and mediotrusive non-functional posterior contacts were eliminated without compromising stable blue MIP contacts. The objective was to establish smooth, continuous guidance along the splint provided exclusively by the mandibular canines, ensuring functional canine guidance. Mandibular movements could then be performed smoothly and without interference, avoiding any sense of a

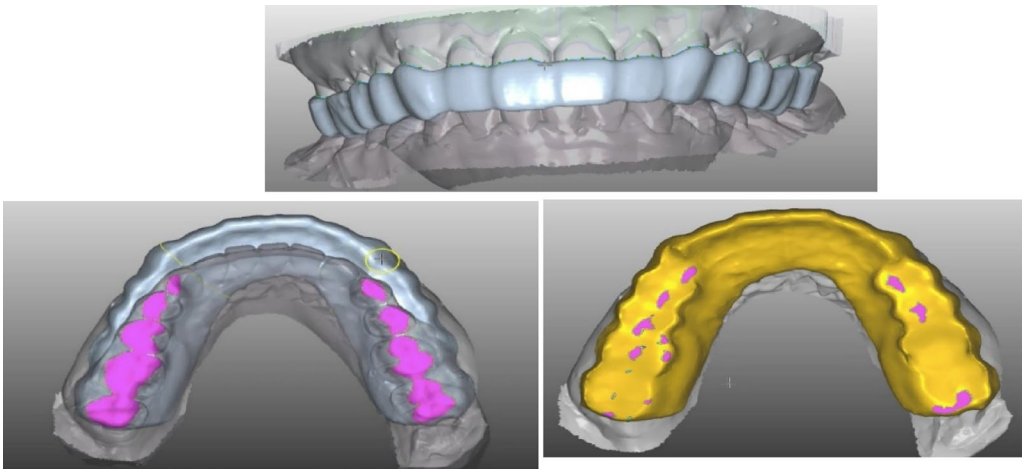

**Fig. 21**. Modeling of the splint. Thickening of splint. Splint surface in contact with mandibular teeth before the adjustment. Splint surface in contact with mandibular teeth after the adjustment

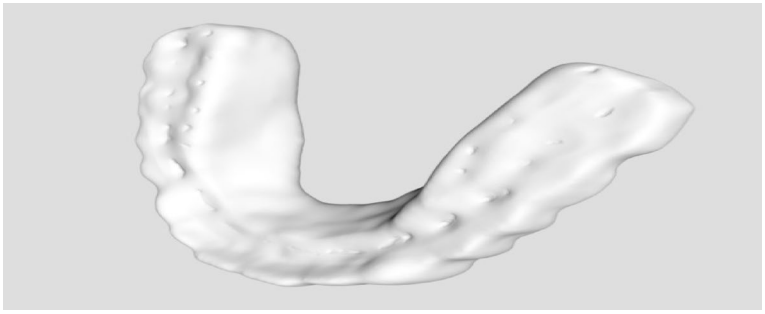

**Fig. 22**. Final .stl file of the splint

boxed-in occlusion due to the splint's excursion design[8,28] (Fig. 10). Splint adjustments were performed under uniform conditions. The same adjustment sequence, instruments, and articulator settings were used for all splints, regardless of the fabrication technique. This approach minimized inter-operator variability and ensured that differences in adaptation and patient perception could be attributed to the splint fabrication method rather than procedural differences.

After gathering all the clinical and laboratory information we undertook a descriptive analysis of the data. The scale variables were computed using Microsoft Excel2007 (Microsoft, Washington, USA) to calculate mean and standard deviation in each of the groups.

This study was approved by the Ethics Committee of Clinical Research of the Dental Hospital of Bellvitge, Universitat de Barcelona (approval code: 2017-19, approval date: 17 December 2019). All methods were performed in accordance with the relevant guidelines and regulations. Informed consent was obtained from all subjects prior to participation in the study.

## Results

The average time consumption required to prepare and mount the cast and articulator in all the techniques was 64.67 min (SD = 4.09 min). Pouring heat-cure fabrication took the longest average processing time 114 min SD = 6.08 min). The vacuum adapted with dough application technique took 92 min (SD = 25.35 min) compared to about 98 min (SD = 6.08 min) in the CAD-CAM workflow.

The mean time of intraoral adjustment of poured heat-cured splints was 28 min (SD = 3,61 min), whereas the mean time of intraoral adjustment of non-CAD-CAM splints was 26,66 min (SD = 3,78 min). It is notable that none of the CAD-CAM manufactured splints conformed completely to the maxillary teeth of participants upon initial delivery, which can be referred by a long arrow in Graphics 1 and 4.

Adapted splint (vacuum) was more advantageous according to the laboratory processing time as opposed to the heat-curing method. Nevertheless, the time of sitting and adjustment of the acrylic splint covered by the heat was comparable to chairside fitting and adjustment of the splint. On the other hand, the CAD-CAM technique was more time consuming as it requires extra steps in digital design, printing out and finishing. Nevertheless, it imposed much less manpower on the dental technician, offloading most of the burdens on the digital workflow (Figs. 25, 26, 27 and 28).


**Fig. 23**. 3D printing device (Formlab form 2[r]) in the left and light-curing device in the right

**Fig. 24**. Delivery of the printed splints

The vacuum-adapted custom-made splint was rated by patients as more comfortable than the poured heat-cured model, due predominantly to better fitment onto the maxillary teeth and resulting in less tightness being experienced (Table 1). This agrees with past research that has documented patient preference in splints that adequately retain without much pressure on teeth or soft tissues[17,31].

The average overall comfort level could not be determined regarding the CAD-CAM splints, due to the fact that none of the appliances seated adequately on the maxillary teeth during intraoral placement, which is comparable with earlier studies reporting difficulty in adapting digitally fabricated occlusal appliances[13,29]. (Table 2)

## Discussion

The aim of this study was to compare the elaboration and adjustment times of three different splint fabrication methods, assess patient comfort during delivery, and describe the limitations of each process.

Pourable heat-cured acrylic splints tend to provide a predictable fit that might need little intraoral modification when the wax imprint accurately represents the arch[11].

The biomechanical behavior of each splint type is strongly influenced by the material's dimensional stability and polymerization characteristics. Conventional poured acrylic splints may experience polymerization shrinkage and thermal distortion, leading to minor inaccuracies in occlusal adaptation. Vacuum-formed thermoplastic splints tend to show excellent initial fit but may deform under intraoral temperature and repeated loading. In contrast, CAD-CAM 3D-printed splints splints, exhibit superior dimensional stability and reduced residual stress. These differences in material properties explain the variations observed in comfort and adaptation across the fabrication methods[40,41].

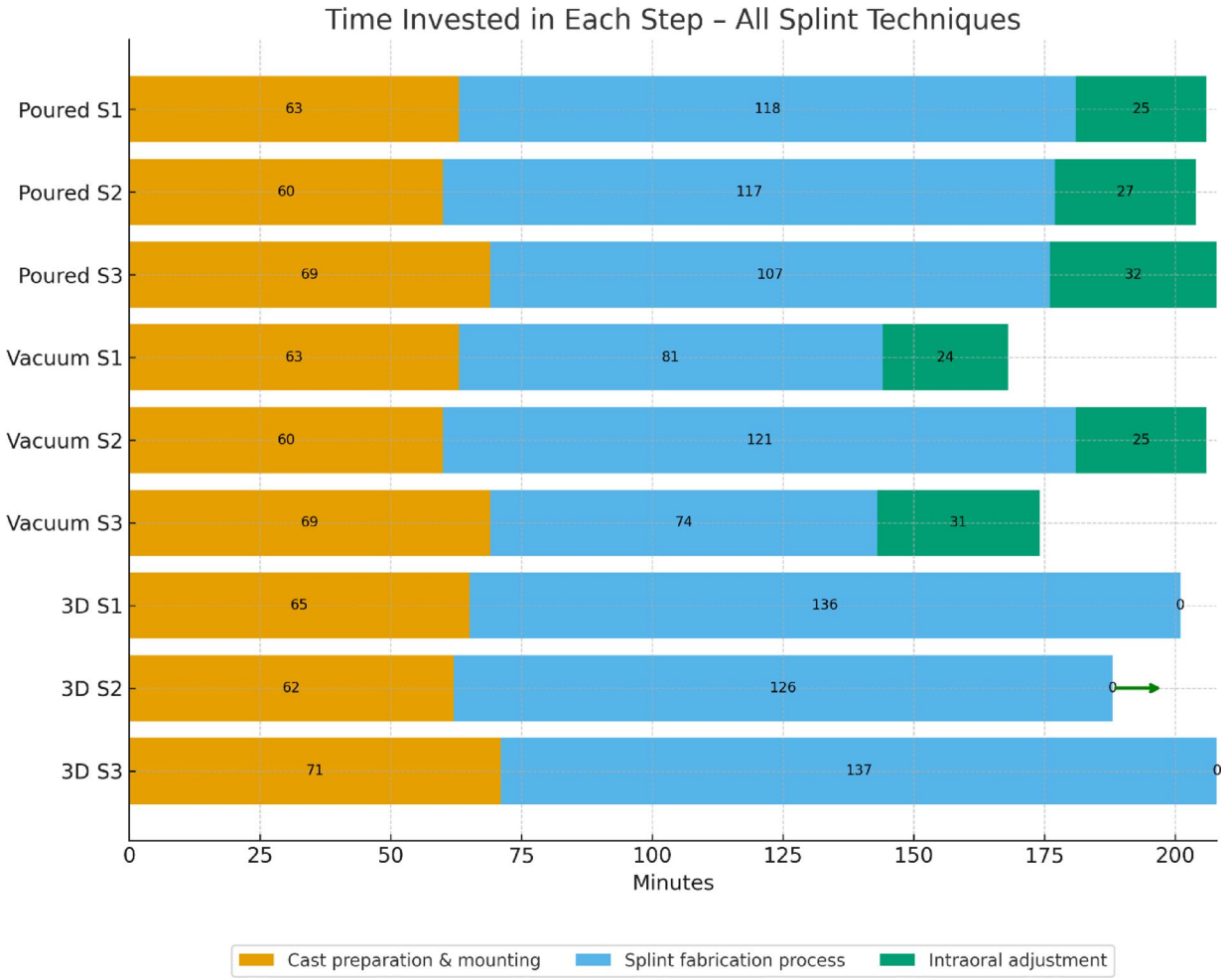


**Fig. 25**. Comparison of time (minutes) invested in cast preparation and mounting, fabrication laboratory process and intraoral adjustment for each of the splints manufactured in this study. We observe the differences between subjects and between elaboration techniques

While some authors suggest that vacuum-adapted splints require little or no chairside adjustment due to reduced processing distortion, claims of their superior dimensional stability compared to heat-cured acrylic splints remain unproven[11].

We found no significant difference in the intraoral adjustment times between the poured heat-cured acrylic splints and the vacuum-adapted splints, and both methods produced adequately smooth acrylic occlusal surfaces. The main difference was in laboratory working time: the vacuum-adapted method required less technician time. However, this time reduction may have limited practical relevance in situations where the laboratory technician is more familiar with, or prefers to use, the poured heat-cured technique. In addition, the poured heat-cured method showed a smaller standard deviation in fabrication time, which may indicate greater consistency. The vacuum-adapted method was more variable, partly due to technical difficulties such as perforation of the splint, which required reapplication of acrylic. Consistent with previous research[10,17], we also found that vacuum-adapted splints fitted better and required less adjustment of the maxillary arch. This method was reported by patients to provide greater comfort, likely due to the improved adaptation of the elastic vacuum sheet to the maxillary cast. Although wax was used to block out undercuts in both fabrication methods, the use of liquids in the poured heat-cured technique often filled small undercuts, creating retentive areas that required further removal during delivery.

This finding can be explained by differences in the dimensional behavior between conventionally processed acrylic splints and those fabricated using digital workflows. Heat-polymerized or poured appliances are susceptible to polymerization shrinkage and storage-related distortion. In contrast, CAD-CAM splints—whether milled from pre-polymerized PMMA blocks or produced by high-precision 3D printing—exhibit improved dimensional stability due to their controlled industrial polymerization and reduced intra-processing stress. In the present study, the digitally fabricated splints were 3D-printed, a technique that has shown lower residual stress and better uniformity compared with traditional processing, although not as dimensionally stable as fully Milled PMMA. These observations are consistent with previous findings[11,40–42]. Patients reported that the poured heat-cured splint was more retentive—and in some cases excessively retentive—and tighter than the vacuum-adapted

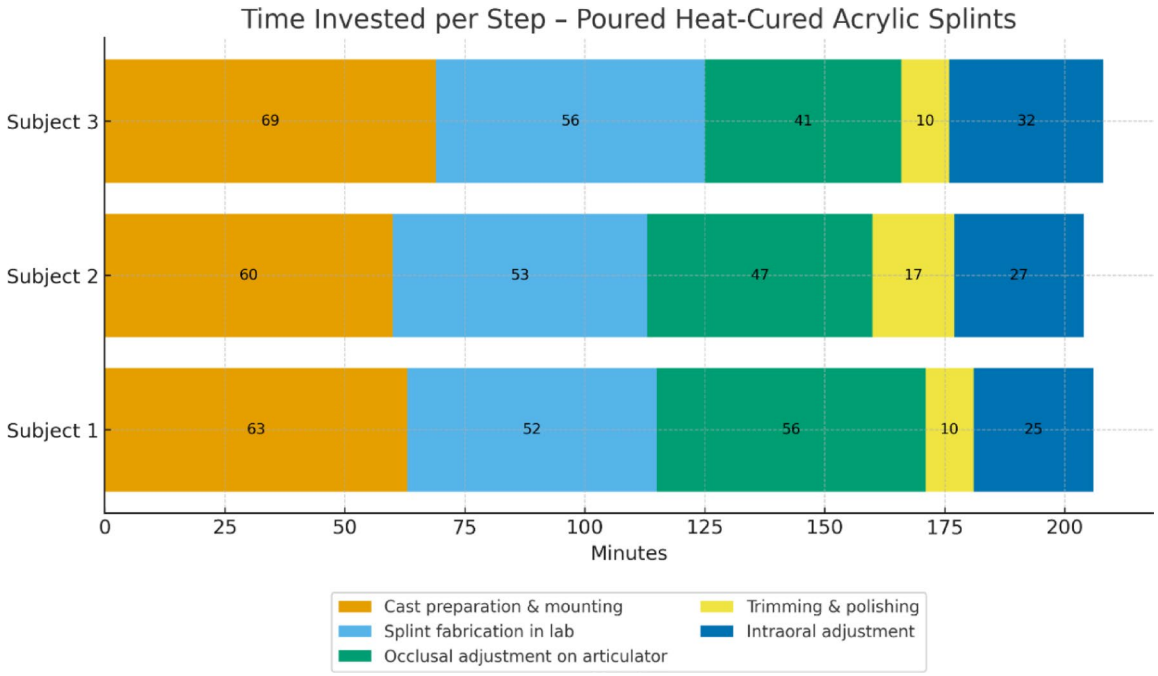


**Fig. 26**. Comparison of time (minutes) invested in each step for the manufacturing of the poured-heat- cured acrylic splint technique between subjects

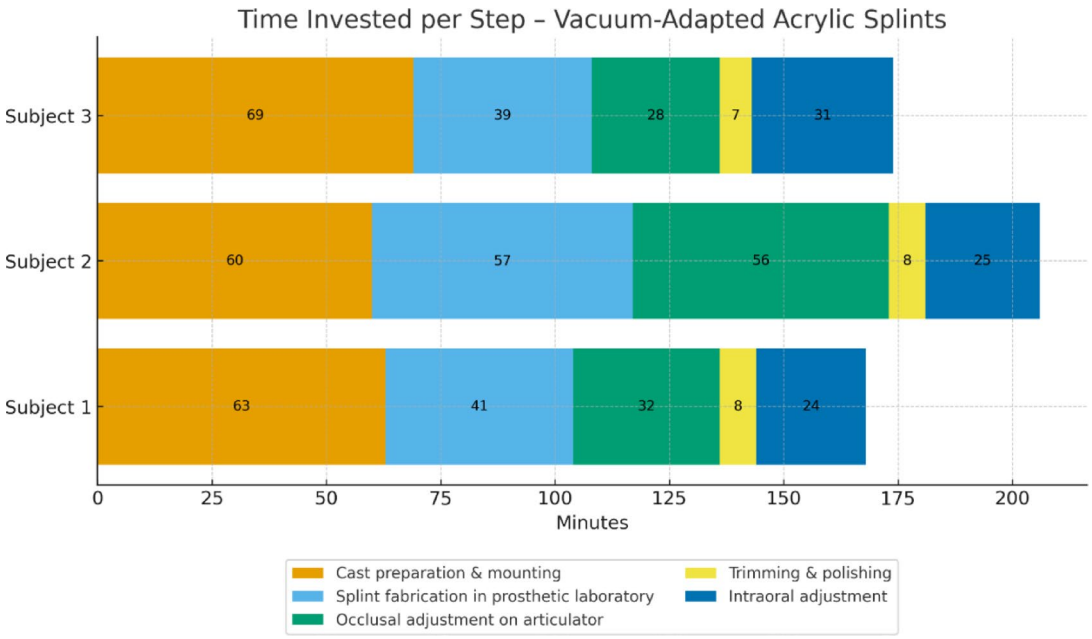


**Fig. 27**. Comparison of time (minutes) invested in each step for the manufacturing of vacuum-adapted splint technique between subjects

splint. This may be attributed to dimensional changes in the acrylic; in poured heat-cured splints, the acrylic is in direct contact with the teeth[11]. Proper fit and patient comfort are essential for the therapeutic success of occlusal splints, yet al.l acrylic-based processing techniques inherently involve minor dimensional changes. Clinicians and laboratory technicians must therefore consider that the fabrication technique can influence the degree to which the material may shrink or expand[4,21]. In this study, Palapress$^{r}$ resin was used; this material demonstrates favorable dimensional stability and reduced water absorption, resulting in more reliable occlusal surfaces[14,21].

As for CAD-CAM splints, digital fabrication provides consistency, quantitative precision, and faster design compared with manual techniques[13–15]. CAD-CAM technology can help overcome several limitations of

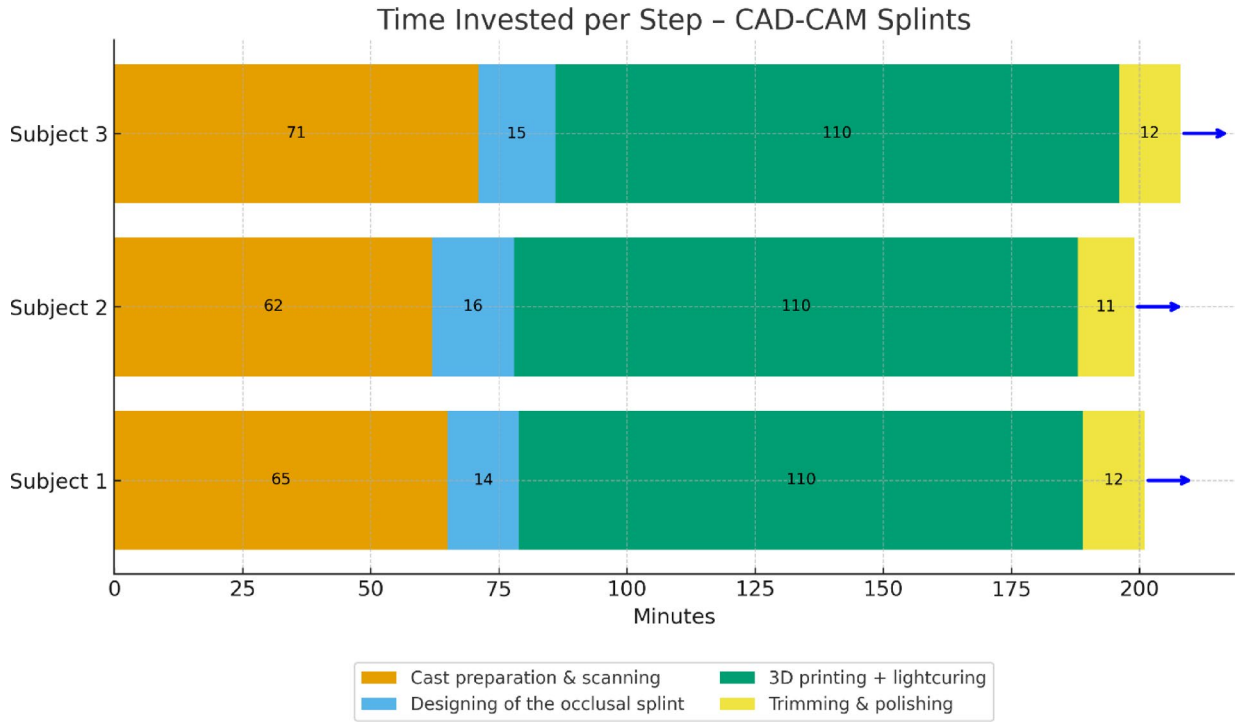


**Fig. 28**. Comparison of time (minutes) invested in each step for the manufacturing of CAD-CAM splint technique between subjects

| | Splint manufacturing technique | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured Splint | | | Vacuum Splint | | | CAD-CAM splint | | |
| | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 |
| **1- How did you feel during the process of adjusting the splint to your maxillary teeth?** | 3 | 4 | 4 | 4 | 4 | 4 | 2 | 1 | 1 |
| **2- How did you feel during the whole adjustment appointment?** | 4 | 4 | 3 | 5 | 5 | 4 | X | X | X |
| **3- How does the splint fit and feel at the end of the appointment?** | 2 | 3 | 3 | 3 | 2 | 4 | X | X | X |
| **Mean** | 3 | 3.7 | 3.3 | 4 | 3.7 | 4 | X | X | X |
| **TOTAL MEAN** | 3.3 | | | 3.9 | | | X | | |

**Table 1**. Results from the VAS questionnaire to assess level of comfort at the adjustment appointment of each splint (S1: subject (1) S2: subject (2) S3: subject 3).(maximum 5, minimum 0).

traditional methods and may even reduce the overall fabrication cycle[29]. In this study, however, CAD-CAM printed splints required more total fabrication time than the other techniques, although the manual labor demanded from the laboratory technician was considerably lower, since one of the most time-consuming steps—the 3D printing process—did not require direct supervision. Although this represents an advantage, it is important to note that both the operation and maintenance of CAD-CAM equipment require specialized skills[13,21].

## Clinical implications digitization of splints

The digital splints are known to possess the accuracy of fit as well as simplified equilibration process. The smooth contour of occlusal contact points is a clear advantage of digitally fabricated devices. Compared to conventional splints, which often leave residual indexing depressions from the opposing cast, custom digital splints offer better outcomes. The smooth finish of digital splints produces only faint markings at occlusal contact points,

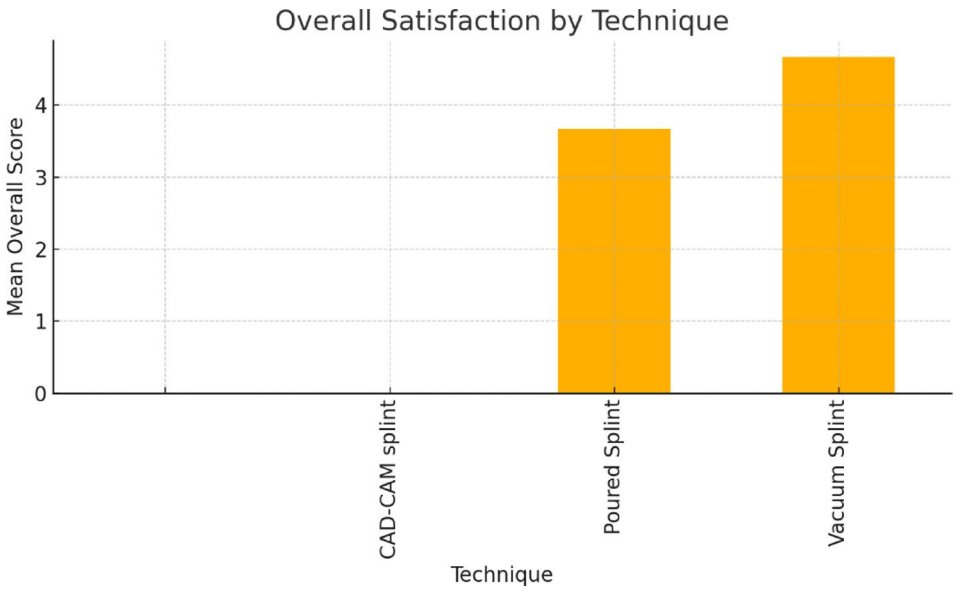


**Table 2**. Overall satisfaction by technique.

unlike the larger and less precise impressions created when articulating paper is used on prominent occlusal surfaces. This precision facilitates selective adjustments and reduces material waste[13,15].

Intraoral occlusal adjustment time for CAD-CAM splints was not measured in this study, as none of the devices fitted properly on the maxillary teeth. Since all splints were fabricated using identical duplicated casts, it is likely that discrepancies occurred during a step in the CAD-CAM manufacturing workflow. Moreover, the light-cured acrylic used in CAD-CAM splints may continue to polymerize after removal. Variability in resin materials among printers and commercial cartridges could also influence fit, an aspect warranting further investigation[13,21].

In spite of such shortcomings, the CAD-CAM technology has evident benefits in recording the patient records. Though in the present study conventional impressions were meant, the use of fully digital impressions has the potential to save patients an unpleasant experience of traditional impression-taking and prevent pouring of casts and mounting them on the articulator[29].

In terms of patient aesthetic evaluation, CAD-CAM printed splints received higher ratings and were preferred over vacuum-adapted splints, which were consistently described as rough and unpolished due to the joint between vacuum-formed plastic and posteriorly added acrylic. Heat-cured acrylic splints were also aesthetically acceptable, though some patients perceived them as bulkier[4,11].

One of the aspects that was not considered in this work was splint storage approaches. The splints were kept at room temperature but previous studies show that acrylic splints in water show reduced linear dimensional change compared to dry splints that tend to distort further[8,11]. It should be noted that, although all splints in this study remained under the same conditions and therefore it is unlikely that this would contribute to differences in the comparative results, storage conditions should be taken into consideration in the further research.

Further studies with larger sample sizes are necessary, as the small sample in this pilot study limited the ability to perform statistically significant comparisons. Future research should focus on direct comparisons between traditional techniques—poured heat-cured acrylic and vacuum-adapted splints—and newer digital methods. The CAD-CAM technique, in particular, demonstrated greater intra-method variability and warrants further investigation. Grid-mounted splints do not undergo dimensional changes as frequently as those mounted on base plates cast on a hydroelectric dam[13,21,29].

Clinically, the selection of a splint fabrication technique should account not only for initial fit and patient comfort but also for long-term durability and cost-effectiveness. In this pilot study, both conventional techniques (poured heat-cured and vacuum-adapted with acrylic) achieved acceptable adaptation following chairside adjustment, while none of the CAD-CAM 3D-printed splints seated completely on the maxillary arch, preventing accurate equilibration.

Although literature supports higher dimensional accuracy in digitally fabricated splints, our findings did not confirm this trend. This discrepancy may be related to design, printing orientation, polymerization behavior, or post-processing variables. Conventional techniques proved more reliable and consistent, with vacuum-adapted splints demonstrating the shortest lab time and highest patient-reported comfort.

These findings highlight the importance of refining digital printing protocols before CAD-CAM printed splints can achieve consistent intraoral adaptation comparable with conventional methods.

Since this pilot study was limited to healthy volunteers, findings related to comfort, fit, and retention may not fully extend to patients with temporomandibular disorders (TMD). These individuals often exhibit varying levels of muscular sensitivity and occlusal dysfunction, which may influence splint effectiveness. Future studies involving symptomatic TMD patients are needed to validate these findings.

## Conclusion

This preliminary study compared three fabrication methods for occlusal splints—conventional pouring, vacuum-adapted, and 3D CAD-CAM Printed techniques. Results indicate that digital workflows reduce clinical chair time during intraoral adjustment. However, all methods presented specific advantages and limitations. While CAD-CAM Printed splints demonstrated high precision and reduced adjustment time, they required greater laboratory investment. Conventional methods remained viable, especially when digital resources are unavailable. Further studies with larger samples and long-term evaluations are necessary to confirm these preliminary findings.

## Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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## Author contributions
Sergi Torné-Durán conceived and designed the study. Laura Marco-Martínez collected the data. Ildefonso Serrano-Belmonte performed the statistical analysis and wrote the manuscript. All authors read and approved the final manuscript.


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## Declarations

## Competing interests
The authors declare no competing interests.

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