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Comparing bending properties of SLA bruxism splint instrumented with sensor: a preliminary study

Lise Valtaud*

URB2I, UR 4462, Université Paris Cité, Montrouge, France

Claudine Wulfman

URB2I, UR 4462, Université Paris Cité, Montrouge, France

Floriane Laverne

URB2I, UR 4462, Université Sorbonne Paris Nord, Montrouge, France

*Corresponding author. Email: lise.valtaud@u-paris.fr

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1. Introduction

The demand for personalized healthcare technologies is driving advancements in instrumented medical devices to meet clinical standards and improve pathology monitoring. Patients with bruxism, a parafunctional disorder, require customized solutions for its prevention, diagnosis, and treatment, such as muscle-relaxation splints (Goldstein et al., 2021).

Additive Manufacturing (AM) enables embedding components during production (Cuellar et al., 2018), allowing the creation of custom-made splints with integrated force sensors to monitor occlusal forces during bruxism (Claude et al., 2019). Ensuring the embedded sensors' integrity and maintaining the mechanical properties of splints are critical. This study evaluates the impact of embedding sensors during AM on the bending properties of test specimens using various manufacturing and post-polymerization parameters, as a step toward developing instrumented bruxism splints.

2. Methods

2.1 Materials and AM equipment

Stereolithography (SLA) is the most widely AM technology used in dentistry for bruxism splints (Nassif et al., 2023). The study is carried out on Formlab equipment:

- Dental LT Clear V2 resin and Formlab 3B printer.
- Form Wash cleaning unit.
- Form Cure L and Fast Cure post-polymerization units.

2.2 Samples design

Splints are subjected to both bending and compression loads (Crout, 2017). Recommended thickness is around 2mm to avoid discomfort (He et al., 2022). Specimens are designed as 60x10x2.1mm parallelepipeds for a three-point bending test. The embedded Polyethylene Naphthalate (PEN) film, commonly used as a sensor substrate, measures 10x6x0.2mm and is positioned 0.3mm below the upper surface to measure occlusion forces. The sensor is placed close to the surface because the goal is to measure the occlusion forces, necessitating proximity to the antagonist. Thus, the sensor is next to the compressive zone and not the traction area.

2.3 Samples manufacturing

Specimens are manufactured flat in the tray center without additional support. The layer thickness is 100µm. Three groups of 20 samples are composed using 3 different AM processes:

- Group 1 (reference): AM without pause or sensor embedment.
- Group 2: AM with a printing pause at the final sensor slot but without sensor embedment.
- Group 3: AM with a printing pause and sensor embedment.

After printing, specimens are cleaned and post-polymerized. Two batches of ten specimens each are created depending on the post-polymerization unit used (Figure 1A):

- Batch A: Form Cure L unit for 60min at T=60°C under 40 LEDs with P= 70W.
- Batch B: Fast Cure unit for 6 min, under 56 LEDs with P=200W.

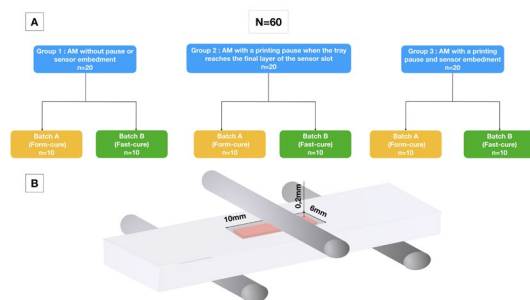


Figure 1. A- Sample manufacturing groups and batches. B- 3-point bending test on a sample with an embedded sensor and slot dimensions Credit: Valtaud

2.4 Samples testing

In order to study whether the pausing, the sensor embedment or the choice of post-polymerization unit affect the bending properties due to modification of the anisotropy and homogeneity of the specimens, 3-point bending tests were achieved on a Shimadzu machine.

2.5 Results analysis

No specimen broke and no delamination was observed. The peak value of the stress-strain curve before stress decrease was considered the maximum flexural strength (σ_m).

Mean values and standard deviations for σ_m and Young modulus (E) were calculated for all groups and batches (Table 1). Non-parametric statistic tests (Kruskal Wallis test) were used for analysis.

Table 1. Mean values \pm SD of flexural strength and Young modulus for the tested groups. Credit: Laverne

Group	Batch	σ_m (MPa)	E (MPa)
G1	A	57,80 \pm 3,44	1912 \pm 56
G2		59,59 \pm 4,23	2001 \pm 64
G3		60,23 \pm 5,53	2041 \pm 127
G1	B	61,14 \pm 4,90	2099 \pm 60
G2		62,96 \pm 6,39	2087 \pm 120
G3		58,93 \pm 6,02	1972 \pm 116

3. Discussion

There is no significant difference between batches or group of a same batch for σ_m . Thus, neither the pausing and sensor embedment nor the choice of a specific post-polymerization unit does alter the maximal flexural strength.

However, for E, test suggests that a difference between groups can be considered within the two batches ($p < 0,05$). Comparing batches 2 by 2, it appears that Group 3 with sensor embedment behaves differently from others for the both batches.

The specimens' stiffness seems to depend on sensor inclusion. This could be explained by the difference in the Young's modulus (E) of the two materials (6 GPa for PEN vs. 2.3 GPa for LT Clear V2). However, surprisingly, the stiffness of Group 3 does not evolve in the same way: it increases by 6.7% for batch A but decreases by 6% for batch B. Therefore, this hypothesis must be rejected. Another explanation could be related to the choice of the post-polymerization process: the Fast Cure unit may cause some damage to the resin due to a supposed higher temperature (induced by higher power). However, since the E values for Groups 1 and 2 are not significantly different, this explanation cannot be retained either. One might imagine that post-polymerization affects the PEN. The temperature of the Fast Cure could lead to degradation of the PEN, causing it to no longer serve as a reinforcement. Macdonald's studies (2012) support our hypothesis. A study of PEN before and after Fast Cure could provide useful insights for splint instrumentation. The decrease of stiffness in batch B could be prohibitive for PEN instrumented bruxism splint post-polymerized with a fast-cure unit.

4. Conclusions

This work is part of a preliminary study aiming to assess the consequences of splint instrumentation. It will be followed by a compression test campaign and the development of numerical models to simulate different sensor thickness, positions in relation to the upper surface. Finally, it will be necessary to compare these results with those obtained with another AM technology used for splints i.e., materiel jetting.

Conflict of Interest Statement: the authors declare that they have no interest in this article.

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