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Odour Perception of In-Office Orthodontic 3D Printing and Its Health Implications

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KEYWORDS

Orthodontic 3D printing; Odour perception; Digital orthodontics; Occupational exposure; In-office aligners.

ABSTRACT:

Introduction: In-office clear aligner fabrication involves the usage of an organic chemical called a polymer resin, for 3D printing, which exposes the orthodontic personnel to possible harmful effects of handling and inhalation of vapours of uncured resin. While mechanical accuracy and efficiency are well documented, sensory and occupational aspects such as odour perception and associated symptoms remain underreported.

Objectives: To evaluate odour perception and associated transient sensory symptoms during in-office orthodontic 3D printing performed under standardized clinical conditions.

Methods: Two commercially available 3D printing resins (SprintRay® Die and Model 2 resin and Taglus® Model resin) were used to print 40 Orthodontic models each with 4 models per day across a 10-day printing schedule. Orthodontic models were printed within a dedicated laboratory environment utilizing a synchronized SprintRay® 3D printing ecosystem. Fifteen assessors perceived odour immediately after printing and at 24 hours using a five-point Likert scale. Transient symptoms including eye irritation and headache were also recorded.

Results: Mean immediate odour scores were higher for SprintRay® Die and Model 2 resin (3.05 ± 0.45) compared with Taglus® Model resin (2.15 ± 0.40). At 24 hours, odour perception decreased for both materials but remained higher for SprintRay® Die and Model 2 resin (2.15 ± 0.40 vs 1.30 ± 0.35). Mild transient symptoms were also similarly reported by the participants.

Conclusion: In-office orthodontic 3D printing demonstrated material-dependent differences in odour perception and mild sensory symptoms. SprintRay® Die and Model 2 resin exhibited higher immediate odour scores compared with Taglus® Model resin, with residual differences persisting at 24 hours. Environmental ventilation and material selection may influence occupational comfort and mitigate health risks in an in-office clear aligner setup.

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1. Introduction

The emergence of additive manufacturing has fundamentally restructured orthodontic workflows, facilitating the rapid, in-office production of diagnostic models, clear aligners, and auxiliary appliances. By integrating stereolithographic technologies directly into the clinical environment, practitioners have significantly diminished traditional laboratory dependency while streamlining digital treatment planning [1–3]. Given the increasing accessibility of compact dental printers and validated resin systems, in-office fabrication has transitioned from a specialized capability to a hallmark of contemporary orthodontic practice [4,5].

Dental photopolymers used in additive manufacturing typically consist of methacrylate oligomers, photo-initiators, stabilizers, and proprietary additives that undergo light-induced polymerization [6]. Although post-curing enhances polymer conversion and mechanical stability, incomplete polymerization may result in residual monomer presence. Previous investigations have highlighted the biological relevance of residual photopolymer components, including cytotoxic and inflammatory responses under experimental conditions [7–9]. While these findings are largely derived from in vitro models, they underscore the importance of understanding real-world exposure dynamics in clinical environments.

Environmental modulation is critical in mitigating the accumulation of airborne byproducts during in-office 3D printing. Beyond biological effects, sensory characteristics such as odour perception represent an important yet underreported aspect of additive manufacturing. Odour generated during photopolymerization may reflect volatilization of residual compounds or polymerization byproducts [10,11]. In enclosed in-office environments, persistent odour may influence operator comfort and perceived environmental tolerability, particularly among clinicians and auxiliary staff exposed repeatedly during daily workflows and also pose health risks in prone individuals. Occupational health literature suggests that symptoms such as ocular or pharyngeal discomfort may serve as early indicators of environmental strain rather than acute toxicological events [12].

The long-term consequences of regular exposure to these chemicals and their impact on the health are yet to be determined. While dedicated laboratory spaces and exhaust ventilation systems are standard regulatory recommendations [13-15], empirical data regarding their efficacy in eliminating odour perception and associated transient symptoms is sparse. The present study addresses this gap by evaluating odour perception and related sensory symptoms during in-office orthodontic fabrication, specifically within a standardized, ventilated 3D printing work-station.

Objectives

The objective of this study was to evaluate material-dependent differences in odour perception and associated transient sensory symptoms during in-office orthodontic 3D printing.

2. Methods

Study Design

This prospective observational study employed a comparative crossover design to evaluate odour perception during routine in-office orthodontic 3D printing using two commercially available 3D printing resins.

3D Printing was conducted using 20 STL files for 10 consecutive working days, with 4 models fabricated per day using each material. This resulted in a total of 80 printed models, including 40 models each fabricated using SprintRay® Die and Model 2 resin and Taglus® Model Resin.

In-office Printing Work-station

Printing was performed using a SprintRay® 3D printer integrated within a dedicated in-office aligner fabrication unit comprising automated isopropyl alcohol washing and post-curing chambers. The workstation was housed in a designated area specifically designed for digital aligner workflows (Figure 1).

Figure 1. In-office aligner workstation with SprintRay® printing, washing, and curing units.

Journal of Chemical Health Risks
www.jchr.org
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The printing environment incorporated an exhaust ventilation system to facilitate air exchange and minimize accumulation of printing-related odours (Figure 2a, 2b).

Figure 2a. Ventilated printing room showing exhaust fan

Figure 2b. Adjacent room showing exhaust tube and airflow system

Material Composition

Two commercially available dental printing materials were evaluated (Figure 3):

•SprintRay® Die and Model 2 resin (SprintRay® Inc., USA), Tan shade

•Taglus® Model resin S (Taglus®, India), Tan shade

Figure 3. Printing materials used in the study.

The composition of SprintRay® Die and Model 2 resin [16] consisted of a blend of methacrylate oligomers and photo-initiators, the precise concentrations of which are not disclosed.

The composition of Taglus® Model resin [17] consisted of aliphatic Urethane Methacrylate (30-50%), Ethoxylated pentaerythritol tetra acrylate (30-50%), 2-acrylic acid, 2- (butylamino) carbonyl) oxy) ethyl ester (2.5-25%), Diphenyl (2,4,6-trimethyl benzoyl) phosphinoxoxide (2.5%), pigment paste (2.5%).

Both materials were used from the same bottles throughout the study period to eliminate batch variability. After printing, models were subjected to automated isopropyl alcohol washing followed by post-curing according to manufacturer-recommended protocols.

Printing Protocol

All prints were performed under standardized conditions between 10:00 AM and 11:00 AM to minimize potential diurnal variations in olfactory perception. Printing parameters including orientation, layer thickness, and post-processing workflows were standardized across all samples. Approximately 10-13 ml of resin was used per model printed. Representative printed models from both materials are shown in Figures 4 and 5.

Figure 4. Orthodontic models printed using SprintRay® Die and Model 2 resin.

Figure 5. Orthodontic models printed using Taglus® Model resin -washed in the SprintRay® automated washer unit

Journal of Chemical Health Risks

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JCHR (2026) 16(2), 404-411 | ISSN:2251-6727

Assessor selection

The present study included 15 assessors, consisting of orthodontic faculty members and orthodontic residents routinely exposed to in-office printing workflows. Assessor blinding was implemented to reduce evaluation bias. Printed models were anonymized and assigned randomized alphanumeric codes prior to assessment. No labelling or visual identifiers indicating the material used was disclosed. Assessors did not report known olfactory disorders at the time of evaluation; were not involved in model fabrication; and were unaware of material allocation throughout the evaluation period.

Outcome Measures

Odour perception was assessed at two time points:

1.Immediately after completion of the printing cycle

2.Twenty-four hours after printing

Assessors rated odour intensity using a five-point Likert scale [18] ranging from no odour to strong odour.

In addition to odour scoring, transient symptoms including eye irritation, headache, throat discomfort, and nausea were recorded to contextualize environmental tolerability, and also assess the health risks.

Statistical Analysis

The coded data was tabulated and Descriptive Statistics including mean and standard deviation were calculated for odour perception scores at both time points. Given the ordinal nature of Likert-scale data, paired comparisons were performed using the Wilcoxon signed-rank test. Effect sizes were estimated using Cohen's d, and significance level of $p < 0.05$ was considered statistically significant.

3. Results

Odour Perception

Immediate odour scores were significantly higher for SprintRay® Die and model 2 resin (3.05 ± 0.45) compared with Taglus® model resin (2.15 ± 0.40; Z = -5.12, $p < 0.0001$). At the 24-hour assessment, odour perception decreased for both materials but remained significantly higher in the SprintRay® group (2.15 ± 0.40 vs 1.30 ± 0.35; Z = -4.78, $p < 0.0001$) (Table 1), (Figure 6).

Table 1: Comparison of Odour Perception Scores between Materials

Time Point	SprintRay® Mean ± SD	Taglus® Mean ± SD	Z-value	p-value
Immediate	3.05 ± 0.45	2.15± 0.40	-5.12	<0.0001*
24 Hours	2.15 ± 0.40	1.30± 0.35	-4.78	<0.0001*

*Statistically significant (Wilcoxon signed-rank test)

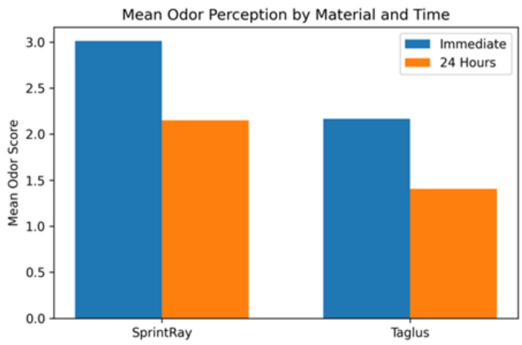

Figure 6. Mean odour perception scores at immediate and 24-hour assessments.

Both materials demonstrated a significant reduction in odour perception over time ($p < 0.0001$), indicating progressive odour dissipation following printing (Table 2).

Table 2: Within-Material Odour Reduction

Material	Immediate Mean	24h Mean	Mean Reduction	p-value
SprintRay	3.05	2.15	0.90	<0.0001
Taglus	2.15	1.30	0.85	<0.0001

Effect size analysis demonstrated a large material-dependent difference in odour perception. The Cohen's d value for immediate odour comparison was approximately 2.1, indicating a very large effect. At the 24-hour evaluation, the effect size remained large (d ≈ 1.8), suggesting persistent material-related sensory differences even after temporal odour reduction. Large effect sizes indicate strong material-dependent sensory differences (Table 3), (Figure 7).

Journal of Chemical Health Risks
www.jchr.org
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Table 3: Effect Size Analysis of material differences

Comparison	Cohen's d	Interpretation
Immediate	2.1	Very large
24 Hours	1.8	Large

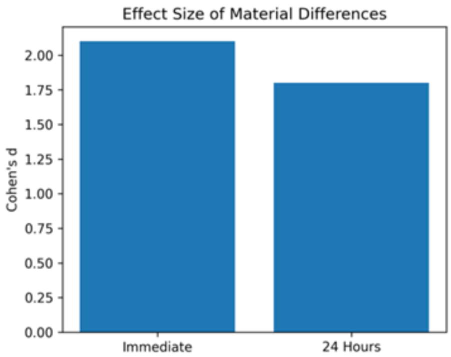

Figure 7. Effect size analysis demonstrating strong material-dependent differences in odour perception.

Frequency distribution analysis revealed that SprintRay® prints were more frequently associated with Moderate and Noticeable odour ratings, whereas Taglus® prints were predominantly associated with Mild and Moderate odour perception (Table 4), (Figure 8).

Table 4: Distribution of Odour Perception Scores (Immediate Assessment)

Odour Score	SprintRay® Die & Model 2 resin	Taglus® Model resin
1 (No odour)	0	6
2 (Mild)	10	22
3 (Moderate)	18	10
4 (Noticeable)	12	2
5 (Strong)	0	0

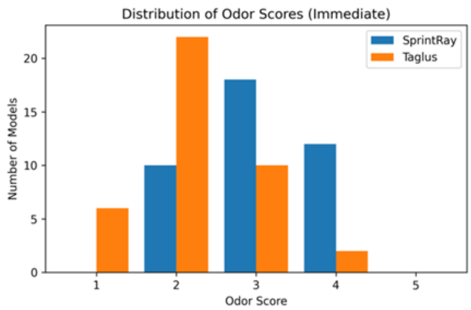

Figure 8. Distribution of immediate odour perception scores across materials.

Transient Symptoms

Transient symptoms were reported more frequently in association with higher odour perception. Immediately after printing, mild eye irritation was reported by 6 of 15 assessors in the SprintRay® group compared with 2 assessors in the Taglus® group. Transient headache was reported by 3 assessors in the SprintRay® group and 1 assessor in the Taglus® group. One assessor reported mild throat irritation in the SprintRay® group (Table 5), (Figure 9).

Table 5: Frequency of Reported Transient Symptoms

Symptom	SprintRay® Immediate	Taglus® Immediate	SprintRay® 24h	Taglus® 24h
Eye irritation	6	2	1	0
Headache	3	1	0	0
Throat irritation	1	0	0	0
Nausea	0	0	0	0

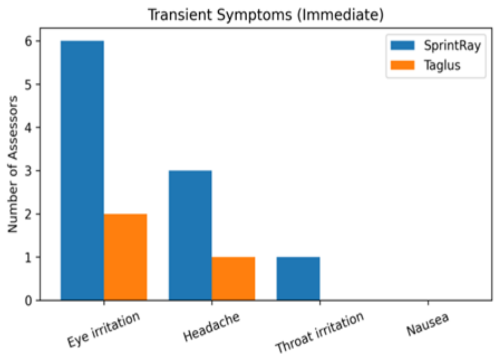

Figure 9. Frequency of transient sensory symptoms associated with each material.

At the 24-hour assessment, symptom frequency declined markedly. Only one assessor reported mild eye irritation in the SprintRay® group, and no symptoms were reported in the Taglus® group. No nausea or severe adverse effects were recorded at any time point (Table 6), (Figure 10).

Journal of Chemical Health Risks
www.jchr.org
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Table 6: Percentage of Assessors Reporting Symptoms

Material	Immediate (%)	24 Hours (%)
SprintRay®	67%	7%
Taglus®	20%	0%

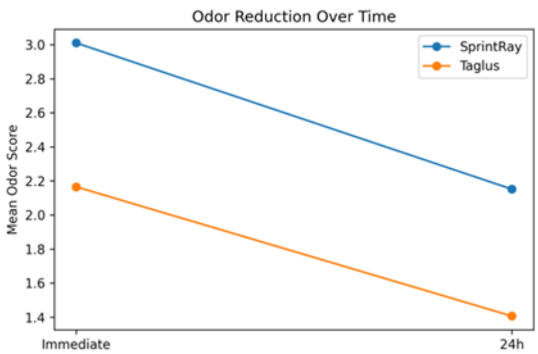

Figure 10. Temporal reduction in odour perception following printing, demonstrating decay in odour intensity over time.

4. Discussion

The present study evaluated odour perception and associated transient sensory symptoms during in-office orthodontic 3D printing performed within a ventilated clinical environment. The findings demonstrated clear material-dependent differences in sensory perception, with SprintRay® Die and Model 2 resin associated with significantly higher odour scores compared with Taglus® Model resin.

Assessing sensory outcomes at two time points helped capture both immediate perception and short-term persistence, which are clinically relevant in routine printing workflows. The noticeable decline in odour intensity at 24 hours suggests that these effects are largely short-lived and reduce with environmental dispersion and continued post-polymer stabilization.

Variations in odour perception may likely be linked to differences in resin chemistry and curing behaviour. 3D printing materials differ in methacrylate composition, photo-initiator systems, which may influence residual compound release and post-curing behaviour [6,7]. Both the materials used in the present study, differed in proprietary photopolymer composition and curing characteristics, which may have influenced polymerization behaviour and may explain the observed sensory variation. Previous literature has suggested that residual photopolymer components may induce oxidative stress responses in oral tissues under experimental conditions [8,9]. These findings provide biological context for interpreting sensory observations.

An additional observation of this study was the presence of mild transient symptoms associated with higher odour perception. Eye irritation and transient headache were more frequently reported in the SprintRay® group immediately after printing. Although these symptoms were self-limiting and resolved spontaneously, they may represent short-term sensory responses to environmental exposure. Similar trends have been reported in occupational health studies, odour perception often reflects environmental discomfort before measurable health effects are evident. [12].

The large effect sizes observed in the present study highlight the practical significance of material-dependent differences in odour perception. The consistently large effect sizes indicate that the sensory disparity between materials is not merely statistical but perceptible in real-world use. Notably, meaningful differences persisted even at 24 hours, suggesting that material-specific characteristics may continue to influence environmental perception despite partial odour dissipation.

Persistent odours in enclosed clinical environments can significantly affect operator comfort and perceived environmental tolerability, particularly for clinical and auxiliary staff exposed repeatedly throughout their daily workflows. Furthermore, these odours may introduce health risks for susceptible individuals. From an occupational perspective, repeated low-level sensory exposure to persistent odour may pose a health risk even in the absence of overt toxicity. The reduction in both odour intensity and symptom frequency at the 24-hour evaluation in the present study, supports the role of ventilation and environmental dilution in mitigating sensory exposure.

All printing in the present study was conducted within a ventilated clinical environment equipped with an exhaust airflow system. The relatively mild symptom profile observed aligns with current recommendations emphasizing the importance of ventilation in in-office 3D printing environment [13–15]. Recent literature also emphasized the importance of evaluating ergonomic and occupational dimensions of digital dentistry alongside technical performance [19–21]. Odour perception may therefore serve as a pragmatic surrogate marker of environmental tolerability and subsequently the rate of chemical dissipation in real-world orthodontic settings.

As in-office orthodontic 3D printing becomes more widespread, balancing material efficiency with user comfort and environmental safety will be important for sustainable integration into clinical practice.

From a practical standpoint, allowing printed models to remain in presence of dedicated ventilation systems, such as exhaust-assisted aligner workstations, immediately after fabrication, may facilitate rapid odour dissipation and reduce operator exposure. Establishing a designated area for in-office clear aligner fabrication that is physically separated from routine clinical spaces may further limit odour dispersion into patient-care environments. In addition, the use of protective masks with filters specifically designed for personnel handling polymer-based materials may offer an additional layer of precaution, particularly in in-office settings [17,18]. These measures represent low-cost, easily implementable strategies that help mitigate occupational health risks without altering existing digital workflows.

5. Conclusion

In-office orthodontic 3D printing demonstrated statistically significant material-dependent differences in odour perception and mild transient sensory symptoms. SprintRay® Die and Model 2 resin exhibited higher immediate odour scores compared with Taglus® Model resin, with residual differences persisting at 24 hours. Mild sensory symptoms were similarly reported, but were transient and self-limiting.

These findings highlight the importance of considering sensory and occupational factors alongside technical performance in digital orthodontics. Adequate ventilation and informed material selection may enhance odour dissipation, mitigate health risk and support responsible integration of in-office clear aligner manufacturing workflows. Additionally, the use of protective masks with cartridges designed for personnel handling polymer-based materials may provide an added precaution and help in mitigating potential exposure-related health risks in busy clinical workflows. Future studies evaluating environmental control strategies and long-term occupational exposure may help refine safety recommendations for digital orthodontic practice.

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