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New Test Methods for Extractables in No-Wipe Topcoat Gel Polish: Extraction and Quantitation of Uncured Monomers After UV Curing

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Abstract: Background: Nail gels are decorative fingernail coatings based on (meth)acrylates that are photopolymerized on the nail surface. After polymerization, these coatings typically retain an uncured layer of monomers at the air interface due to oxygen inhibition, which may pose a risk of skin sensitization unless removed. No-wipe topcoats are formulated to address this issue by curing fully; however, no standard test method exists to verify a complete cure. This study presents a method to quantify residual uncured traces of several common nail gel monomers extracted from polymerized commercial no-wipe nail gels. Method: Commercially available no-wipe nail gels were formed into films of controlled thickness and polymerized using a standard UV-curing nail lamp. Solvent extraction was employed to eliminate residual uncured monomers, namely diethylene glycol dimethacrylate (DEGDMA), isobornyl acrylate (IBOA), and 2-hydroxyethyl methacrylate (HEMA). These monomers were quantified utilizing GC-FID and HPLC techniques. Method validation was conducted with samples of known monomer identity and concentration, thereby establishing specificity, linearity, precision, and detection limits. Results: Validated test protocols were established for the analysis of residual uncured traces of three commonly used monomers in nail gel coatings. In all instances, levels of monomer residue in a cured gel coating were found to range from 56 µg/g to 800 µg/g. Tests conducted on commercial products indicated that levels of these monomers fell within the expected normal ranges for such products. Conclusions: Through the utilization of two chromatographic techniques, three analytical methods were established for the simultaneous determination of ingredient concentrations and residual monomer quantities in unreacted bulk formula and cured UV-gel film. These methods and the resultant data facilitate the evaluation of curing completeness, which is essential for product development and safety assessments.

Keywords: diethylene glycol dimethacrylate; isobornyl acrylate; 2-hydroxyethyl methacrylate; gel nail polish; gas chromatography with flame ionization detection; high-performance liquid chromatography; residual

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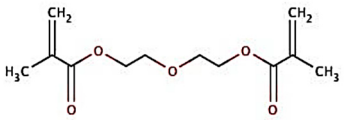
1. Introduction

UV-curable fingernail coatings, commonly referred to as "gel nail polish", are used for color and sculpting purposes. These products consist of various (meth)acrylate compounds that are photopolymerized into nail-coating films after 2 min of UV nail lamp exposure. It is assumed that the large, polymerized molecules cannot be penetrated, and any remaining residue becomes trapped within the hardened polymer matrix, resulting in minimal potential for systemic exposure. The nail salon industry considers gel nail

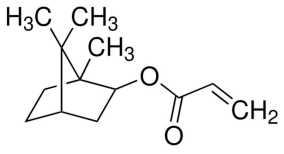
polishes beneficial due to their low odor compared to traditional solvent-based nail lacquers and liquid-powder sculpting systems. However, improper use of gel nail polish products may present a risk for the development of allergic contact dermatitis (ACD) in both consumers and professionals [1–7], primarily caused by repeated skin contact with uncured (meth)acrylate monomers [8–10]. During the curing process, oxygen inhibits free radical acrylic polymerization at the air–product interface, leaving an uncured layer on the surface known as the "tacky layer", which must be removed by professional nail technicians using isopropanol. Failure to do so can compromise the aesthetic appearance of the nail coating and potentially expose clients to uncured reactive materials, thereby increasing the risk of acquiring ACD.

To address this limitation, the cosmetic industry has dedicated significant efforts to develop "tack-free" or no-wipe UV curable nail topcoats. These no-wipe topcoats are designed to ensure complete curing of reactive monomers, thereby eliminating the need for a post-cure cleansing step to remove any layer of incompletely cured monomers. Consequently, analytical verification of the absence of uncured monomers at levels that could pose a potential health risk is a necessary product safety measure. This confirmation allows the elimination of the wiping step from user instructions and the proper education of technicians on the application of no-wipe topcoat products [11–23].

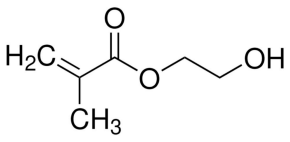
While quantitative methods have been developed for studying the penetration of topical onychomycosis treatments, studies focusing on the penetration of nail care ingredients are few and far between. Chromatography is an optimal method for identifying and quantifying residual monomers released from resin materials. Techniques such as gas chromatography with flame ionization detection (GC-FID) and high-performance liquid chromatography (HPLC) have been employed to monitor the release of monomeric substances from resins [24–29]. To date, there has not been an analytical method developed specifically for monitoring residual, unpolymerized (meth)acrylates in no-wipe topcoat gels. This study introduces three methods to investigate the residual uncured materials of diethylene glycol dimethacrylate (DEGDMA), isobornyl-2-acrylate (IBOA), and 2-hydroxyethyl methacrylate (HEMA), all of which are potential sensitizers found in no-wipe topcoat gels. The research presented herein determined the levels of DEGDMA and IBOA using GC-FID, along with HPLC analysis of the HEMA found in commercially available gel products. It is anticipated that the findings of this study will contribute to product safety evaluations aimed at assessing the risks of not removing the uncured layer of the product after application. The structure of these compounds can be found in Figure 1.



Di (ethylene glycol) Dimethacrylate



Isobornyl Acrylate



2-Hydroxyethyl Methacrylate

Figure 1. Structure of DEGDMA, IBOA, and HEMA.

2. Materials and Methods

2.1. Materials

Di (ethylene glycol) dimethacrylate 95% CAS 2358-84-1, isobornyl acrylate 91.3% CAS 5888-33-5, and 2-hydroxyethyl methacrylate ≥ 99% CAS 868-77-9 were purchased from Millipore Sigma (Milwaukee, WI, USA). Artificial perspiration, ISO 3160-stabilized [30]. Acetonitrile (MeCN), ethyl alcohol, and methanol of HPLC grade were purchased from VWR (Secaucus, NJ, USA). Casting film entailed the use of a bar film applicator, a Model BYK stainless steel 3 mil wet film drawdown single bar 6 No. 5566, a clear four mil polyester substrate from BYK with 5.00 × 7.63 in dimensions. Finally, no-wipe nail topcoats of various brands were purchased at ordinary commercial outlets.

2.2. Instrumentation

A Perkin Elmer Clarus 580 GC (Shelton, CT, USA) equipped with a flame-ionization detector and an automated liquid sampler. The columns used were from Restek (Bellefonte, PA, USA): a Stabilwax 30 m, i.d. 0.25 mm, 0.25 µm coating thickness and an Elite 5MS 30 m, i.d. 0.25 mm, 0.25 µm coating thickness;

A Perkin Elmer Altus HPLC equipped with a UV-DAD detection system. The column used was an ACE Super-C18, 3.0 µm, 4.6 × 100 mm^2 from Avantor VWR (Visalia, CA, USA);

An OPI "Starlight" UV-LED nail-curing lamp (Wella, Calabasas, CA, USA), with dual peak outputs at 365 nm and 405 nm wavelengths;

A BYK automatic film applicator: model Byko-drive auto applicator BYK No. 2121 (Geretsried, Germany);

A vacuum pump: model BYK No.3879. (Geretsried, Germany)

2.3. Standard Preparation

Stock solutions of DEGDMA, IBOA, and HEMA at 1000 µg/mL were prepared by weighing 0.015 g of each material into 15 mL of their respective solvents as provided in Table 1. Each was placed in a 15 mL polyethylene tube with a screw cap. Working standard solutions of DEGDMA ranged from 2.2 µg/mL to 217 µg/mL and were prepared by diluting the stock solution with acetonitrile. Working standard solutions of IBOA ranged from 1.2 µg/mL to 250 µg/mL and were prepared by diluting the stock solution with ethanol. Finally, working standard solutions of HEMA ranged from 1.2 µg/mL to 250 µg/mL and were prepared by diluting the stock solution with methanol. All standards were filtered using 0.45 µ PVDF membrane filters.

Table 1. Stability of analytes.

Monomer	Solvent	Concentration (µg/mL)	Time	% Loss
DEGDMA	Acetonitrile	3.3	1 h	2.4
IBOA	Ethanol	1.3	24 h	2.4
HEMA	Methanol	1.4	24 h	0.9

2.4. HPLC and GC-FID Sample Preparation

To quantify the analytes in commercially available cosmetic products, samples were prepared using a 15 mL polyethylene tube with a screw cap. Precisely 0.05 g of the bulk product was weighed and 10 mL of the appropriate solvent was added. The mixture was vortexed for 1 min and then placed in an ultrasonic bath for 20 min. Following sonication, the tubes were vortexed again and subsequently filtered using a PVDF membrane filter.

2.5. High Performance Liquid Chromatography Operating Procedure

The chromatograph utilized was a Perkin Elmer Altus HPLC equipped with a UV-DAD detector and Empower software for data analysis. The analytical column employed was an ACE Super-C18, 3.0 µm, 4.6 × 100 mm^2. The mobile phase consisted of 0.1% phosphoric acid in water and acetonitrile, pumped at a flow rate of 0.8 mL/min as per the gradient outlined in Table 2. Detection of HEMA was facilitated through maximum UV absorption at a wavelength of 210 nm. Additional acquisition parameters are detailed in Table 2. Accurate retention times and calibration curves were derived from standard injections, and the signal from cosmetic samples was validated by matching the retention time of the analyte.

Table 2. HEMA gradient.

Column	ACE Super-C18, 3.0 µm, 4.6 × 100 mm^2, Cat#: 10829-210 (Avantor, VWR)) OR Equivalent	
Mobile phase	**A**: 0.1% Phosphoric Acid + Water **B**: Acetonitrile	
Gradient	Time (min)	B/A
	0	25/75
	4	25/75
	5	99/1
	7	99/1
	8	25/75
Flow rate (mL/min)	0.8	
Detector	UV/Vis	
Wavelength (nm)	210	
Scan	250–400	
Injection vol. (µL)	5.0	
Run Time: (min)	15	
Column Temp. (°C)	25	

2.6. Film Generation

No-wipe topcoat films were prepared using a BYK 3 mil wet drawdown bar and an automatic film applicator operating at a speed of 1 in/sec (25.4 mm/s) on polyester film. Prior to the drawdown process, the polyester film was outlined to match the finger guide on the OPI Starlight lamp hand piece (Figure 2). The 3 mil wet thickness of the film replicated the thickness of a brush application on fingernails. The product-coated film was then placed on a cardboard stand to simulate the average height of a hand at 0.5 inches. Each coated film was irradiated at 365 nm at 11 mw/cm^2 and 405 nm at 13 mw/cm^2 using the OPI Starlight lamp for the exposure time recommended in the instructions of each commercially available product, ranging from 30 to 60 s. Following the curing process, the drawdown substrate was cut to match the size of the outlined finger area.



Figure 2. Cardboard stand with polyester substrate outlined to duplicate the finger guide of the OPI Starlight lamp.

2.7. Extraction Method

The worst-case scenario test, designed to obtain the maximum amount of extracted monomer, is typically conducted with pure organic solvents such as acetonitrile, isopropanol, or hexane, depending on the solubility of the analyte. The optimal selection of solvents should emulate the effects of skin secretions, as this will dictate the extractability of the analytes under consumer-relevant conditions. Consequently, the simulation test is often performed with saline or aqueous solutions that contain a low concentration of organic solvents. This general methodology is most advantageous for the comprehensive risk assessment required for regulatory approval. However, for targeted analysis, it is imperative that the compound remains stable in the extraction medium within a specified timeframe. Solvent entry into the polymer network causes the polymer structure to expand, thereby facilitating the extraction of unreacted monomers. To examine the stability of these compounds, analytes were dissolved in their respective organic solvents and subsequently analyzed at two time points: initially and after 1 h or 24 h, as detailed in Table 1.

The stability investigation revealed that DEGDMA at a concentration ten times higher (31 µg/mL) than indicated in Table 1, and experienced a 30% degradation within 24 h. Consequently, conducting the extraction with a strong organic solvent such as acetonitrile required only a 1 h extraction period, as the amount of unreacted DEGDMA would be significantly lower. Settings for the GC-FID instrument used to monitor DEGDMA and IBOA are summarized in Tables 3 and 4. The HPLC method utilized an Ace Excel 2 Super C18 100× 4.6 analytical column maintained at 25 °C. Each sample, five microliters in volume, was injected, and the analyte was detected at 210 nm using the gradient method outlined in Table 4.

The surface areas of the film corresponding to the typical positions of the thumb, middle, and index fingers within the UV nail lamp were excised, weighed, and subsequently placed into a 2 mL flat-bottom centrifuge tube for the addition of 1 mL of solvent. The tube was then vortexed at 3000 rpm for 30 s both prior to and following incubation under the specified conditions outlined in Table 1 before sampling. Following extraction, the eluate was transferred into GC vials for analysis. To determine the film's weight, exclusive of the polyethylene substrate, the sample was removed from the tube and placed on an aluminum weigh boat for drying. Upon drying, the film was separated from the substrate, and the weight of the film was recorded as the sample weight.

Table 3. DEGDMA experimental setting for gas chromatography with flame ionization detector measurements.

GC	Injection volume	1 µL		
	GC-column	Stabilwax 30 m, i.d. 0.25 mm, 0.25 µm coating thickness		
	Purge gas/flow	Helium, 1.59 mL/min		
	Temperature program	Rate (°C/min)	Temperature (°C)	Time (min)
			80	0.5
		25	210	6
	Injector temp.	270 °C		
	Split	1/10		
FID	Base temperature	310 °C		
	Air flow	450 mL/min		
	Hydrogen flow	45 mL/min		
	Make-up gas flow	45 mL/min		

Abbreviations: FID, flame-ionization detector. GC, gas chromatography.

Table 4. IBOA experimental setting for gas chromatography with flame ionization detector measurements.

GC	Injection volume	1 µL		
	GC-column	Elite 5MS 30 m, i.d. 0.25 mm, 0.25 µm coating thickness		
	Purge gas/flow	Helium, 1.59 mL/min		
	Temperature program	Rate (°C/min)	Temperature (°C)	Time (min)
			40	0.5
		25	310	2
	Injector temperature	250 °C		
	Split	1/40		
FID	Base temperature	310 °C		
	Air flow	450 mL/min		
	Hydrogen flow	45 mL/min		
	Make-up gas flow	45 mL/min		

3. Results and Discussion

Validation for HPLC and GC-FID

The proposed method was validated for specificity, linearity, system precision, recovery, and sensitivity [31] using GC-FID for DEGDMA and IBOA, in addition to HPLC for HEMA.

3.1. Specificity

No interfering peaks were observed at the retention times of DEGDMA, IBOA, and HEMA when the diluent (ethanol or methanol) was introduced into the system. The chromatograms of IBOA and DEGDMA obtained using GC-FID are presented in Figures 3 and 4, respectively. The HPLC chromatogram of HEMA is depicted in Figure 5. The methods employed were devoid of interference from the diluents used and demonstrated specificity for all three monomers.

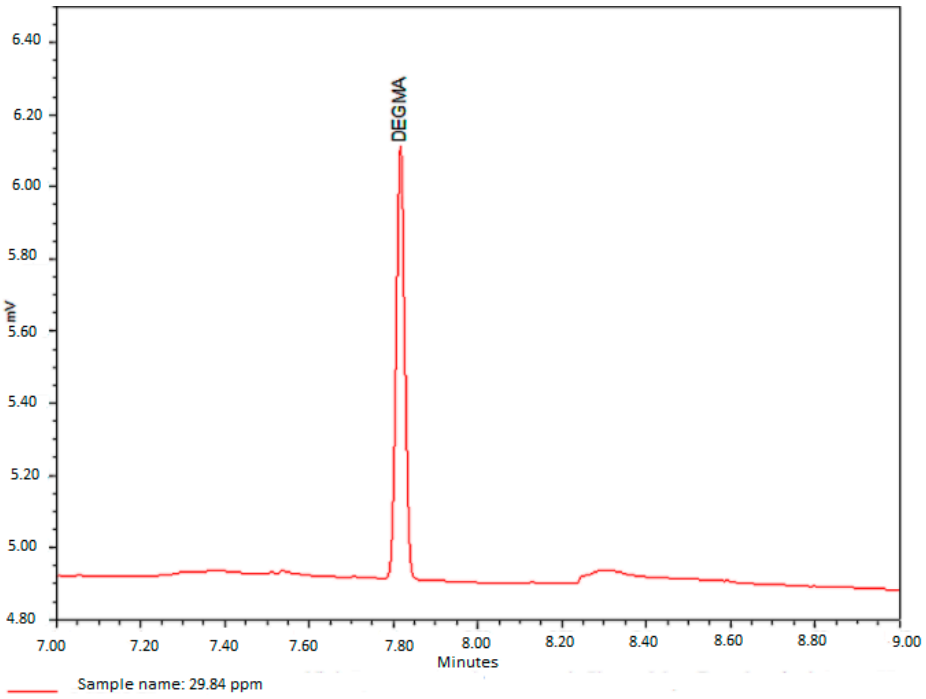


Figure 3. Example of gas chromatography with flame-ionization detector chromatogram of 29.8 ppm of DEGDMA (section from 7.00 min to 9.00 min, DEGDMA peak is at 7.85 min).

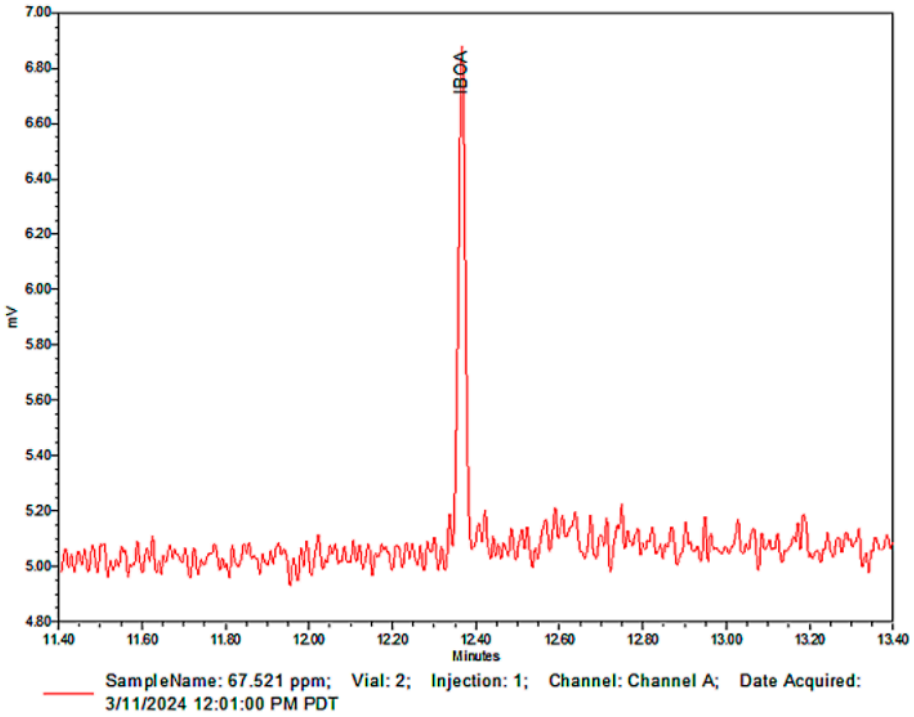


Figure 4. Example of gas chromatography with flame-ionization detector chromatogram of 67.5 ppm working standard of IBOA (section from 11.40 min to 13.40 min, IBOA peak is at 12.42 min).

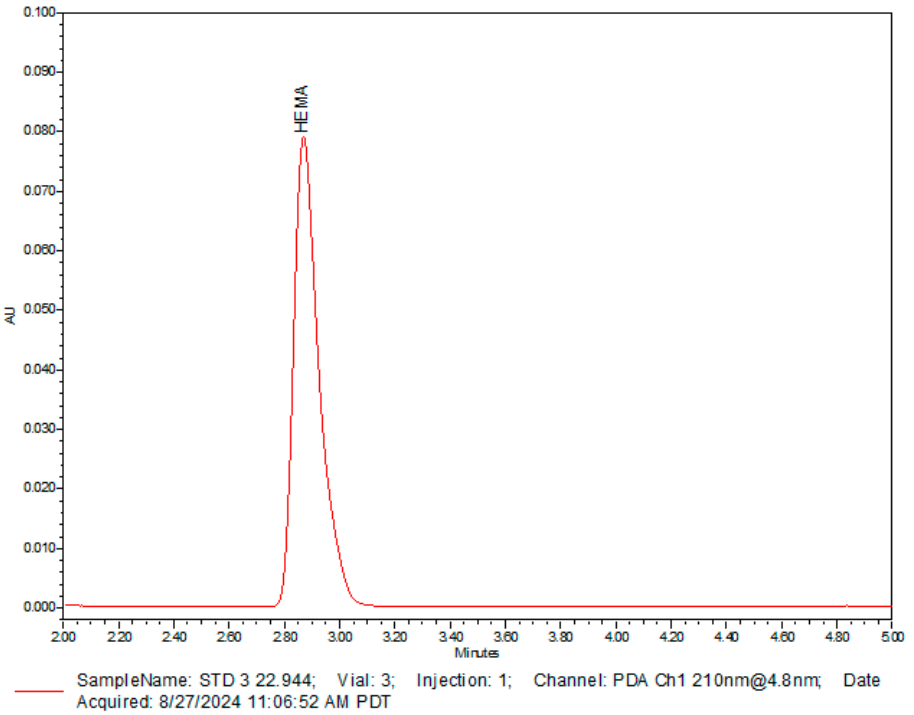


Figure 5. Example of gas chromatography with flame-ionization detector chromatogram of 22.9 ppm HEMA (section from 2.00 min to 5.00 min, HEMA peak is at 2.97 min).

3.2. Linearity

Linearity standards were established by serially diluting each stock solution to produce three distinct concentration levels. The peak areas corresponding to each level were calculated to evaluate the method's linearity, accompanied by graphs plotting the peak area against each respective concentration. The linear calibration equation for each monomer is detailed in Table 5, with calibration curve plots for each analyte presented in Figures 6–8.

Table 5. Linear calibration equation for each monomer.

Monomer	r^2	Equation
DEGDMA	0.999	$Y = 5.12 \times 10^{1}x + 1.01 \times 10^{-2}$
IBOA	0.999	$Y = 3.13 \times 10^{1}x - 4.51 \times 10^{-1}$
HEMA	1.000	$Y = 2.18 \times 10^{4}x - 7.03 \times 10^{3}$

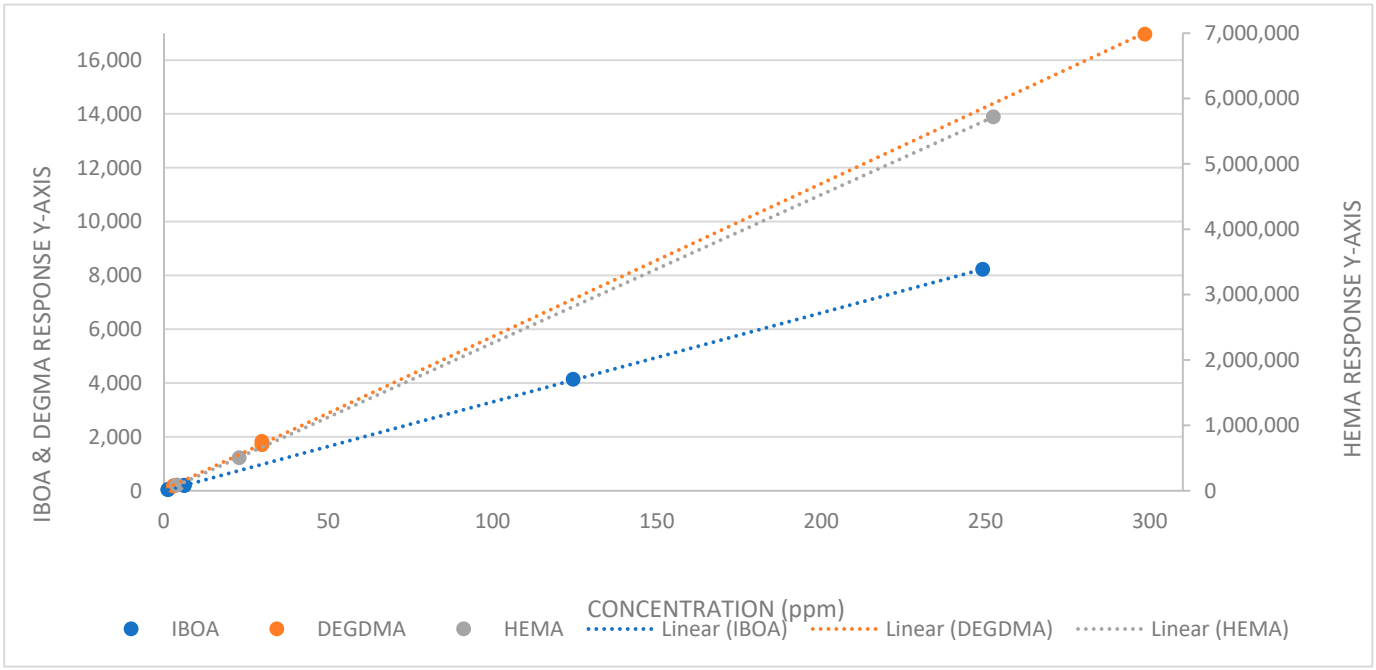


Figure 6. Calibration curve example for DEGDMA, IBOA, and HEMA.

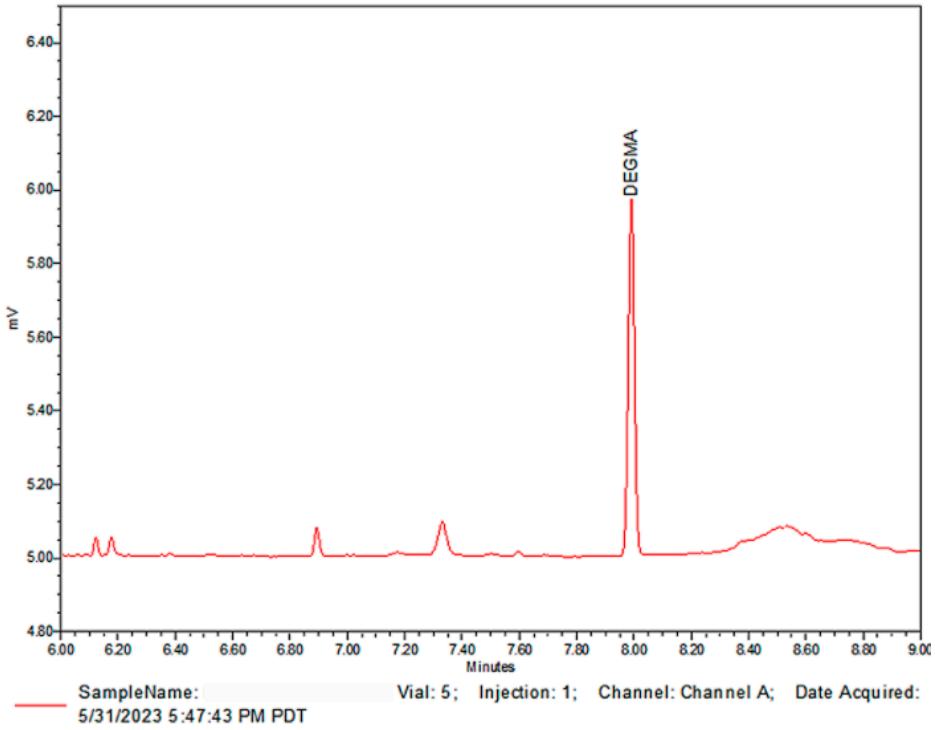


Figure 7. Chromatogram of DEGDMA peak at 7.85 min found in a commercially available product.

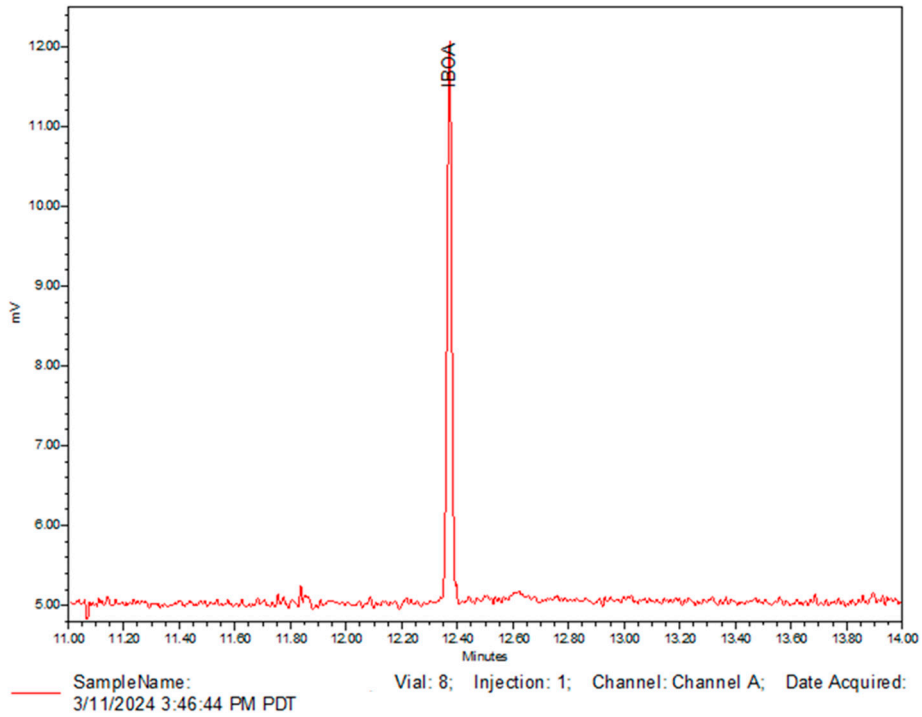


Figure 8. Chromatogram of IBOA peak at 12.42 min found in a commercially available product.

3.3. System Precision

System precision was assessed by measuring the variability of the system using the peak area from five injections with a single standard, as presented in Table 6. The low % RSD indicates that the analytical system is capable of precisely measuring each of the components.

Table 6. System precision data for DEGDMA, IBOA, and HEMA.

(No. Replicates)	DEGDMA	IBOA	HEMA
		Peak Area (μV × s)	
1	2427.7	36.8	24,064.0
2	2442.1	36.6	24,232.8
3	2416.8	37.4	24,256.2
4	2399.3	37.3	23,999.8
5	2356.2	36.8	24,270.4
Average	2408.4	37.0	24,164.6
Std Dev.	33.1	0.3	124.0
RSD	1.4	1.0	0.5

3.4. Limit of Detection and Quantification Limit

One of the ways to determine the LOD and LOQ according to the International Committee on Harmonization (ICH) is based on the standard deviation of the response and slope [32]. Standards for each analyte were developed using a series of concentrations, which can be seen in Table 7. The LOD and LOQ were calculated using the equations below based on the standard deviation of the calibration curve shown in Table 8. Limit of detection LOD = 3.3σ/S and Limit of Quantitation LOQ = 10σ/S, where S = the slope of the calibration curve and σ = the coefficient of residual standard deviations of the regression line.

Table 7. DEGDMA, IBOA, and HEMA standards used for LOD and LOQ calculations.

µg/mL	DEGDMA Peak Area (µVs)	µg/mL	IBOA Peak Area (µVs)	µg/mL	HEMA Peak Area (µVs)
0.6	17.0	0.7	17.6	0.7	13,673.9
1.2	32.0	1.3	32.8	1.3	22,234.5
2.0	52.2	3.1	89.0	2.0	40,971.1
3.0	80.0	5.0	148.1	3.3	70,446.3

Table 8. Limit of detection and limit of quantitation.

Monomer	LOD (µg/mL)	LOQ (µg/mL)
DEGDMA	0.2	0.4
IBOA	0.1	0.3
HEMA	0.5	1.5

3.5. Recovery

Spike recovery experiments were undertaken to identify potential matrix effects that could influence the results, evaluate the method's accuracy, and confirm its suitability for this specific sample type. These recovery experiments were performed in triplicate by spiking commercially available gel topcoat with DEGDMA, IBOA, and HEMA at two levels, ranging from approximately 20 to 250 ppm, as detailed in Table 9. The recovery for each level adhered to acceptance criteria between 97–105%. These results demonstrated that the analytical method is accurate and free from significant matrix effects interference.

Table 9. DEGDMA, IBOA, and HEMA percent recoveries.

(No. Replicates)	DEGDMA		IBOA		HEMA	
Standards	21.4 ppm	287.8 ppm	23.3 ppm	232.6 ppm	23.0 ppm	249.7 ppm
1	100.7	96.3	101.6	99.8	101.7	99.4
2	103.1	99.3	107.3	102.5	103.1	98.7
3	98.0	97.0	111.4	99.6	104.0	99.5
Average	100.6	97.6	106.8	100.6	102.9	99.2
Std Dev.	2.6	1.6	4.9	1.6	1.2	0.4
RSD	2.6	1.6	4.6	1.6	1.1	0.4

3.6. Bulk Assays

The methodologies described were employed for the identification and quantitative analysis of DEGDMA, IBOA, and HEMA in three commercially available UV gel products. These products were chosen based on the presence of one of the three monomers listed on their labels, according to the INCI (International Nomenclature for Cosmetic Ingredients). Repeatability measurements of the products were conducted to assess the consistency of results, as indicated in Table 10, demonstrating that the analytical methods are reliable and produce consistent outcomes. Accordingly, as illustrated in Table 11, the final method was utilized for the duplicate quantitation of each of the monomers found in their respective products. The chromatograms of these products are presented in Figures 7–9. The additional peaks observed are attributed to other ingredients typically present in gel formulas, such as monomers, inhibitors, stabilizers, and photoinitiators, among others.

Table 10. DEGDMA, IBOA, and HEMA repeatability measurements in commercially available bulk samples.

(No. Replicates)	DEGDMA	IBOA Peak Area (μs)	HEMA
1	1533.6	7775.2	2,243,596.6
2	1473.5	8693.3	2,292,909.7
Average	1503.6	8234.3	2,268,253.2
Std Dev.	42.5	649.2	34,869.7
RSD	2.8	7.9	1.5

Table 11. Quantitative determination of each monomer found in commercially available bulk samples.

Product #	Monomer	Amount (%)	% RSD
1	DEGDMA	14.24	3.06
2	IBOA	29.0	3.08
3	HEMA	15.3	3.90

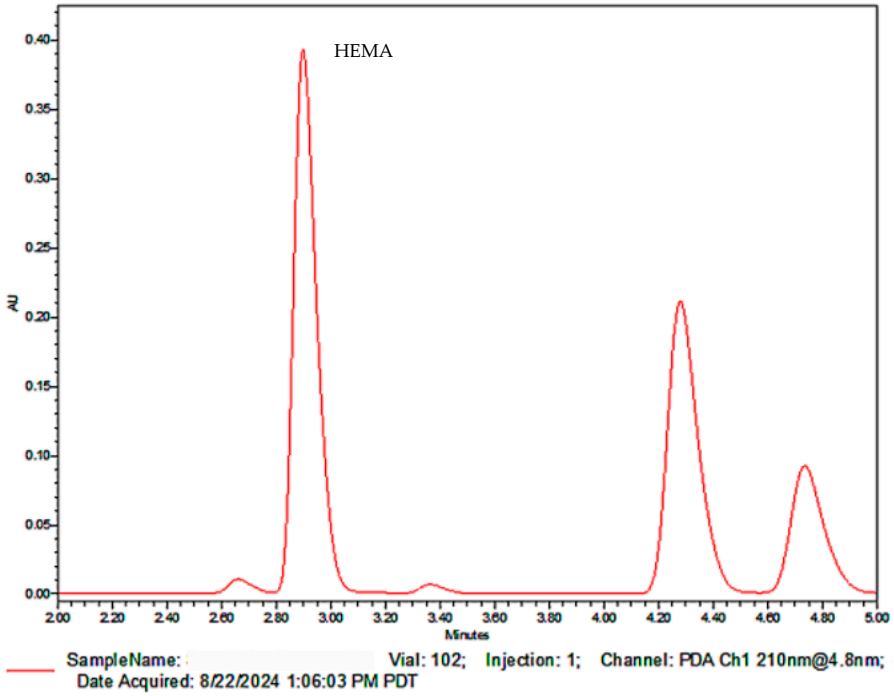


Figure 9. Chromatogram of HEMA peak at 2.97 min found in a commercially available product.

3.7. Residual Assays

UV-gel films of three commercially available no-wipe topcoat gel products were produced, and the extraction of monomers was conducted according to the sample preparation protocol mentioned above. The residual levels of each analyte found in the cured UV-gel films were determined using the developed analytical methods and calculated using the weight of the film, as summarized in Table 12. The levels of the remaining monomers in the products after UV-curing were minimal. These results align with the chemical kinetics of the highly reactive monomers found in UV gel nail products [33,34]. Additional peaks exhibited in chromatograms (Figures 10–12) indicate that the materials found in these films may lead to in situ side reactions during the extraction process, which involves the use of a solvent and heat.

Table 12. Residual levels of the monomers found in gel films of commercial products.

Product #	Monomer	Amount (µg/g)
1	DEGDMA	800
2	IBOA	56
3	HEMA	139

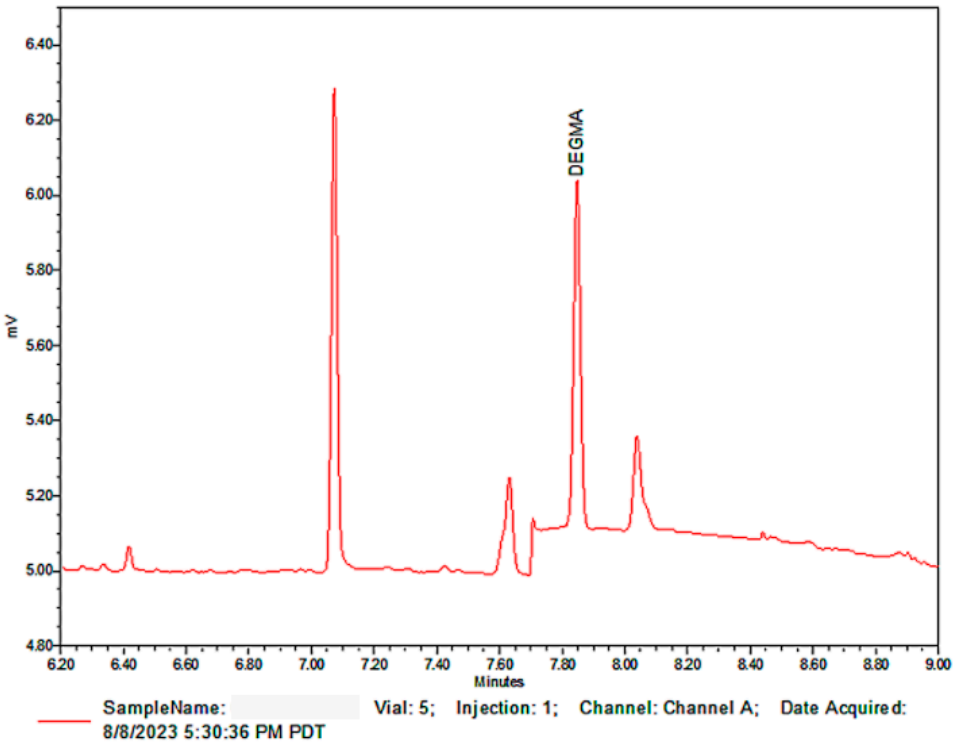


Figure 10. GC-FID chromatogram of DEGDMA found in a commercially available product film.

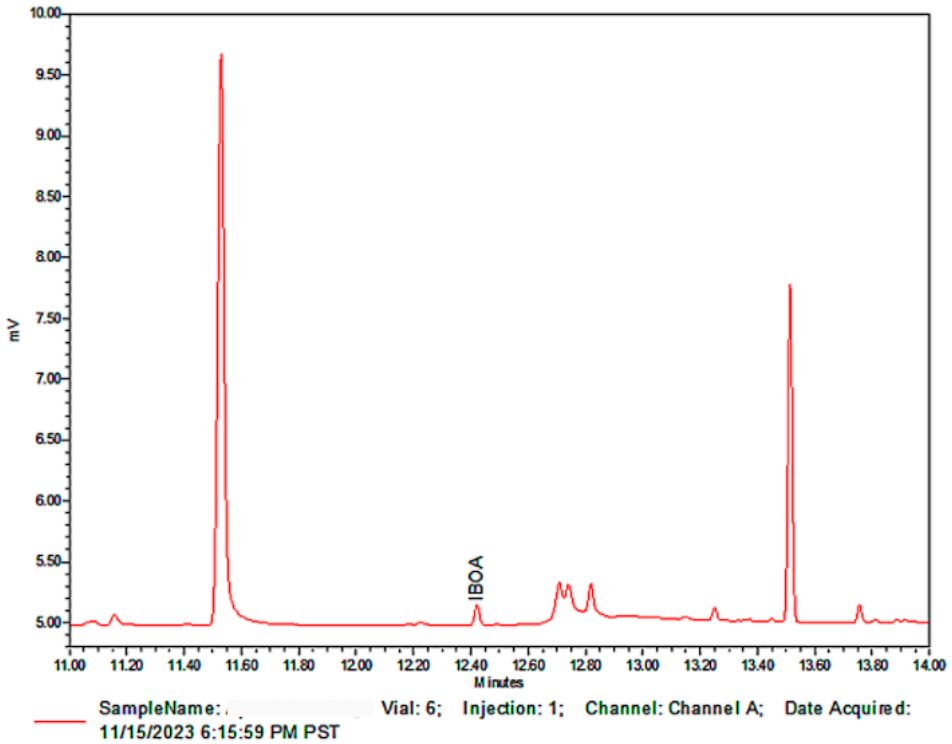


Figure 11. GC-FID chromatogram of IBOA found in a commercially available product film.

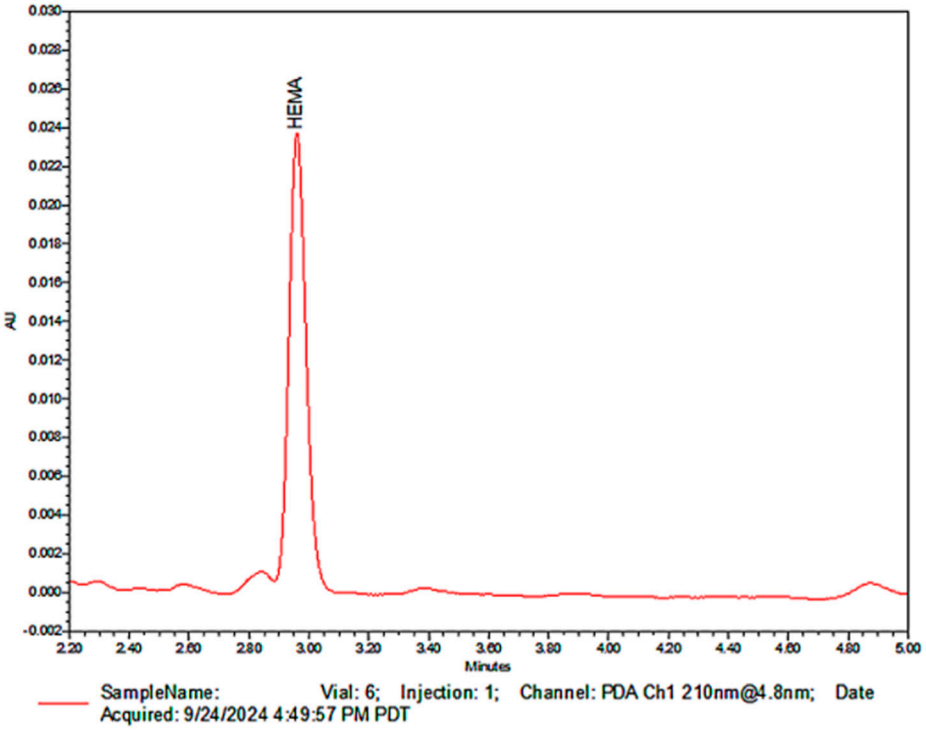


Figure 12. GC-FID chromatogram of HEMA found in a commercially available product film.

4. Conclusions

Two chromatographic techniques, GC-FID and HPLC, were utilized to develop three analytical methods for the simultaneous analysis of DEGDMA, IBOA, and HEMA monomers in the bulk formulas of commercially available products. Their sensitivity demonstrates that these methods are effective in determining the residual levels of the three monomers after UV-curing of no-wipe topcoat gel products. These methods showed no interference from the diluent used in the preparation of the products and demonstrated specificity for the three analytes. The system precision is adequate, indicating the reliability of the analytical system to precisely measure each component. Additionally, the repeatability of the quantitative determination of the monomers in bulk samples is acceptable.

These methods were validated and shown to be specific and accurate for the analysis of DEGDMA, IBOA, and HEMA found in UV gel products. The levels of analytes remaining in the cured film were low due to the high reaction kinetics of the monomers during the polymerization process. Furthermore, even under worst-case conditions, where the analytes were extracted using an organic solvent with higher solubility compared to artificial sweat, the extractable monomers content was less than 0.1%. These methods can be utilized to assess skin exposure to individual acrylate monomers with sensitizing properties, facilitating a thorough safety assessment of no-wipe topcoats.

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References

1. Bernauer, U.; Bodin, L.; Celleno, L.; Chaudhry, Q.; Coenraads, P.J.; Dusinska, M.; Ezendam, J.; Gaffet, E.; Galli, C.L.; Granum, B.; et al. *OPINION ON the Safety of Cosmetic Ingredients HEMA and Di-HEMA Trimethylhexyl Dicarbamate"—Submission I—(Sensitisation Only)*; hal-01672529; Publications Office of the European Union: Luxembourg, 2017.
2. Arora, H.; Tosti, A. Safety and efficacy of nail products. *Cosmetics* **2017**, *4*, 24. [CrossRef]
3. Zembala, P.; Zembala, J.; Zembala, R.; Adamowicz, D.; Gacoń, E.; Łopuszyńska, I. Emerging Trends in Gel Nail Allergies: Prevalence, Symptoms, and Occupational Hazards Associated With Acrylate Sensitization. *J. Educ. Health Sport.* **2023**, *45*, 57–75.
4. Gonçalo, M.; Pinho, A.; Agner, T.; Andersen, K.E.; Bruze, M.; Diepgen, T.; Foti, C.; Giménez-Arnau, A.; Goossens, A.; Johanssen, J.D.; et al. Allergic contact dermatitis caused by nail acrylates in Europe. An EECDRG study. *Contact Dermat.* **2018**, *78*, 254–260.
5. Andersen, S.L.; Rastogi, S.C.; Andersen, K.E. Occupational allergic contact dermatitis to hydroxyethyl methacrylate (2-HEMA) in a manicurist. *Contact. Dermat.* **2009**, *61*, 48–50. [CrossRef] [PubMed]
6. Steffier, L. *HEMA, HPMA & Polyurethane (Meth)acrylate Oligomer Extraction Report*; Keystone Research & Pharmaceutical: Cherry Hill, NJ, USA, 2016.
7. Mohammad-Reza, K.; Mahmoud, G. Determination of migration monomer styrene from GPPS (general purpose polystyrene) and HIPS (high impact polystyrene) cups to hot drinks. *Toxicol. Mech. Methods* **2009**, *19*, 257–261.
8. Lee, H.; Pokorny, C.; Law, S.; Pratt, M.; Sasseville, D.; Storrs, F. Cross-reactivity among epoxy acrylates and bisphenol F epoxy resins in patients with bisphenol A epoxy resin sensitivity. *Am. J. Contact Dermat.* **2002**, *13*, 108–115.
9. Ferracane, J.L.; Greener, E.H. The effect of resin formulation on the degree of conversion and mechanical properties of dental restorative resins. *J. Biomed. Mater. Res.* **1986**, *20*, 121–131.
10. Brown, R.P. Allowable limits for toxic leachables: Practical use of ISO 10993-17 standard. *Woohead Publ. Ser. Biomater.* **2012**, *50*, 95–119.
11. Yin, X.J.; Hewitt, N.J.; Erler, S.; Bryson, P.; Blömeke, B.; Gaspari, A.A.; Goebel, C. Safety assessment for nail cosmetics: Framework for the estimation of systemic exposure through the nail plate. *Regul. Toxicol. Pharmacol.* **2024**, *148*, 105588. [CrossRef]
12. Bernard, M.; Jubeli, E.; Pungente, M.D.; Yagoubi, N. Biocompatability of polymer-based biomaterials and medical devices-regulations, in vitro screening and risk-management. *Biomater. Sci.* **2018**, *8*, 2025–2053.
13. De Jong, W.H.; Carraway, J.W.; Geertsma, R.E. Invivo and invitro testing for the biological safety evaluation of biomaterials and medical devices. *Woodhead Publ. Ser. Biomater.* **2012**, *50*, 95–119.
14. Kucharczyk, M.; Słowik-Rylska, M.; Cyran-Stemplewska, S.; Gieroń, M.; Nowak-Starz, G.; Kręcisz, B. Acrylates as a significant causes of allergic contact dermatitis—New sources of exposure. *Adv. Dermatol. Allergol.* **2021**, *38*, 555–560. [CrossRef] [PubMed]
15. Herman, A.; Aerts, O.; Baeck, M.; Bruze, M.; De Block, C.; Goossens, A.; Hamnerius, N.; Huygens, S.; Maiter, D.; Tennstedt, D.; et al. Allergic contact dermatitis caused by isobornyl acrylate in Freestyle® Libre, a newly introduced glucose sensor. *Contact Dermatitis* **2017**, *6*, 367–373. [CrossRef] [PubMed]
16. Kamann, S.; Aerts, O.; Heinemann, L. Further evidence of severe allergic contact dermatitis from isobornyl acrylate while using a continuous glucose monitoring system. *J. Diabetes Sci. Technol.* **2018**, *3*, 630–633. [CrossRef]
17. Albert, D.E. The important role of material and chemical characterisation in device evaluation. *Med. Device Technol.* **2004**, *5*, 15–18.
18. Santerre, J.P.; Shajii, L.; Leung, B.W. Relation of dental composite formulations to their degradation and the release of hydrolyzed polymeric-resin-derived products. *Crit. Rev. Oral. Biol. Med.* **2001**, *12*, 136–151. [CrossRef]
19. Dunn, W.J.; Bush, A.C. A comparison of polymerization by light-emitting diode and halogenbased light-curing units. *J. Am. Dent. Assoc.* **2002**, *133*, 335–341. [CrossRef]
20. Cadenaro, M.; Antoniolli, F.; Sauro, S.; Tay, F.R.; Di Lenarda, R.; Prati, C.; Biasotto, M.; Contardo, L.; Breschi, L. Degree of conversion permeability of dental adhesives. *Eur. J. Oral. Sci.* **2005**, *113*, 525–530. [CrossRef]
21. Altintas, S.H.; Usumez, A. Evaluation of monomer leaching from a dual cured resin cement. *J. Biomed. Mater. Res. Part. B Appl. Biomater.* **2008**, *86*, 523–529. [CrossRef]
22. Komurcuoglu, E.; Olmez, S.; Vural, N. Evaluation of residual monomer elimination methods in three different fissure sealants in vitro. *J. Oral. Rehabil.* **2005**, *32*, 116–121. [CrossRef]
23. Sideridou, I.D.; Achilias, D.S. Elution study of unreacted Bis-GMA, TEGDMA, UDMA, and Bis-EMA from light-cured dental resins and resin composites using HPLC. *J. Biomed. Mater. Res. Part. B Appl. Biomater.* **2005**, *74*, 617–626. [CrossRef] [PubMed]
24. Altintas, S.H.; Usumez, A. HPLC analysis of HEMA released from two different adhesive systems. *J. Biomed. Mater. Res. Part B Appl. Biomater.* **2009**, *91*, 924–929. [CrossRef] [PubMed]
25. Hezenci, Y.; Akdeniz, B.S. Comparison of residual monomer amounts released from indirect bonding adhesives. *Angle Orthod.* **2023**, *93*, 558–565. [CrossRef] [PubMed]

26. Botsali, M.S.; Sozer, A.S.; Altunsoy, M.; Demir, A.; Ulker, H.E. Residual monomer release from orthodontic adhesives cured with different light sources. *J. Adhes. Sci. Technol.* **2016**, *30*, 1354–1363. [CrossRef]
27. Altunsoy, M.; Selim Botsali, M.; Ulker, H.E. Evaluation of HEMA released from four different adhesive systems by HPLC. *J. Appl. Biomater. Funct. Mater.* **2015**, *13*, e100–e105. [CrossRef]
28. Fink, H.; de Barros Fernandes, N.M.; Weissmann, J.; Frey, M. Extraction With Sweat-Sebum Emulsion as a New Test Method for Leachables in Patch-Based Medical Devices, Illustrated by Assessment of Isobornylacrylate (IBOA) in Diabetes Products. *J. Diabetes Sci. Technol.* **2021**, *15*, 792–800. [CrossRef]
29. Zhang, H.; Wang, Z.; Liu, O. Development and validation of a GC-FID method for quantitative analysis of oleic acid and related fatty acids. *J. Pharm. Anal.* **2015**, *5*, 223–230. [CrossRef]
30. *ISO 3160*; Artificial Perspiration ISO-3160-Stabilized. Biochemazone: Leduc, AB, Canada, 2023.
31. Skoog, X.; Holler, F.J. *Fundamentals of Analytical Chemistry*, 7th ed.; Saunders College Publishing: Orlando, FL, USA, 1996; p. 55.
32. Peter, S. ICHGuideline, Q2B, Validation of analytical procedures: Methodology. In Proceedings of the International Conference on Harmonization, Yokohama, Japan, 6 November 1996.
33. Cook, W.D. Photopolymerization Kinteics of Dimethacrylates Using Camphorquinone Amine Initiator System. *Polymer* **1992**, *33*, 600–609. [CrossRef]
34. Goodner, M.D.; Lee, H.R.; Bowman, C.N. Method for Determining the Kinetic Parameters in Diffusion-Controlled Free-Radical Homopolymerization. *Ind. Eng. Chem. Res.* **1997**, *36*, 1247–1252. [CrossRef]

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