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Thermoformed Thermoplastic Sheets in Pediatric Dentistry- A Comprehensive Narrative Review of Material Science, Digital Workflows, and Clinical Evidence.

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Abstract:

***Background**: **Background:** Thermoformed thermoplastic sheets have become integral to modern pediatric dental practice, spanning trauma management, orthodontics, preventive dentistry, craniofacial rehabilitation, and restorative care. Despite their widespread use, the literature remains fragmented, and comprehensive evidence synthesis is lacking.*

***Objective:** This narrative review critically evaluates the evolution, material properties, manufacturing techniques, digital workflows, and clinical applications of thermoformed sheets in pediatric dentistry, while identifying knowledge gaps and future research priorities.*

***Methods:** A comprehensive literature search was conducted across PubMed, Scopus, Embase, Web of Science, and Cochrane Library databases from inception to August 2026. Search terms included "thermoforming," "thermoplastic," "pediatric dentistry," "clear aligner," "mouthguard," "cap splint," "nasoalveolar molding," and related MeSH terms. Studies were selected based on relevance to pediatric applications, with emphasis on systematic reviews, randomized controlled trials (RCTs), prospective studies, and material science investigations. Evidence was graded according to the Oxford Centre for Evidence-Based Medicine (OCEBM) levels.*

***Results:** PETG (T_g ~80–85°C), EVA, polycarbonate, polypropylene, and multilayer polyurethanes each exhibit distinct mechanical, optical, and biological profiles that dictate clinical indications. Pressure thermoforming yields superior adaptation and reduced thinning compared with vacuum thermoforming. Digital workflows improve accuracy but introduce variables related to resin stability during thermoforming heating cycles. Clear aligner therapy in mixed dentition shows promising outcomes for transverse expansion and anterior crossbite correction, though skeletal changes remain modest compared with functional appliances. Custom thermoformed mouthguards demonstrate superior fit and shock absorption versus stock alternatives. Thermoformed cap splints and intermaxillary fixation appliances offer conservative trauma management, but evidence is primarily Level IV. In craniofacial rehabilitation, thermoformed feeding plates and nasoalveolar molding (NAM) appliances provide lightweight alternatives to acrylic, though NAM requires serial appliance replacement rather than chairside relining.*

***Conclusions:** Thermoformed appliances represent a versatile, minimally invasive treatment modality across pediatric dental subspecialties. However, high-quality prospective studies and RCTs are urgently needed to establish standardized protocols, particularly for trauma splints, functional orthopedic modifications, and craniofacial appliances. Material selection must be individualized based on polymer properties, anticipated functional loads, and biological safety profiles.*

***Keywords:** thermoforming, pediatric dentistry, clear aligners, mouthguards, dental trauma, nasoalveolar molding, PETG, digital workflow*

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I. Introduction

The convergence of advanced polymer science and digital manufacturing has fundamentally reshaped contemporary dental practice, enabling patient-specific, minimally invasive, and esthetically acceptable treatment modalities. Among these innovations, thermoformed thermoplastic sheets have emerged as versatile substrates for fabricating removable and fixed dental appliances. Their excellent adaptability, optical clarity, biocompatibility, and ease of fabrication have cemented their role across pediatric dentistry, orthodontics, prosthodontics, restorative dentistry, and maxillofacial rehabilitation [1,2].

Thermoplastic polymers were introduced to dentistry in the mid-twentieth century as alternatives to conventional heat-cured polymethyl methacrylate (PMMA). Early applications were confined largely to removable prostheses and occlusal splints; however, successive advances in polymer chemistry have yielded high-performance materials—including polyethylene terephthalate glycol (PETG), ethylene-vinyl acetate (EVA), polypropylene (PP), polycarbonate (PC), thermoplastic polyurethane (TPU), and multilayer copolymers—with markedly improved mechanical, optical, and biological characteristics [3,4]. These developments have expanded the clinical repertoire of thermoformed appliances far beyond orthodontic retainers to encompass trauma splints, functional appliances, obturators, nasoalveolar molding (NAM) devices, mouthguards, occlusal splints, fluoride trays, restorative templates, and surgical guides [3,4].

Thermoformed sheets are prefabricated thermoplastic polymers that become pliable when heated above their glass transition temperature (T_g) and can be accurately adapted over a dental cast or digitally manufactured model. Upon cooling, the material regains rigidity while retaining the adapted shape without irreversible chemical cross-linking—a behavior that distinguishes thermoplastics from thermosetting resins. The capacity for repeated heating and reshaping, combined with dimensional stability and transparency, renders these materials particularly suitable for customized dental appliances [1,3].

Two principal thermoforming techniques dominate dental fabrication: vacuum thermoforming, which utilizes negative pressure to adapt a heated sheet over a cast, and pressure thermoforming, which employs compressed air to force the softened material onto the model under positive pressure. Vacuum thermoforming remains the most common technique due to its simplicity and affordability, whereas pressure thermoforming offers superior adaptation, improved surface detail reproduction, reduced material thinning, and enhanced dimensional accuracy—advantages that are clinically significant for orthodontic retainers, trauma splints, and surgical templates [1,5].

Pediatric dentistry presents distinctive challenges arising from the anatomical, physiological, behavioral, and psychological attributes of growing children. Successful treatment requires appliances that are comfortable, esthetic, minimally invasive, and capable of achieving therapeutic objectives while preserving patient cooperation. Conventional acrylic appliances, though widely used, are frequently associated with increased bulk, compromised esthetics, potential residual monomer release, greater laboratory complexity, and wire components that may reduce comfort. Thermoformed appliances address many of these limitations by providing lightweight, transparent, accurately fitting, and well-tolerated alternatives that improve esthetics, speech, oral hygiene maintenance, and overall acceptance [1,6].

Despite the expanding use of thermoformed appliances, the literature remains fragmented, with most reports focusing on individual appliances or isolated clinical scenarios. To date, no comprehensive review has integrated the evolution of thermoplastic materials, fabrication techniques, material characteristics, and the diverse clinical applications of thermoformed sheets within pediatric dental practice. Accordingly, this narrative review aims to critically evaluate the evidence base, guide clinicians in material and appliance selection, and identify current knowledge gaps and future research priorities.

II. Methodology

This narrative review was structured according to the Scale for the Assessment of Narrative Review Articles (SANRA) criteria [7]. A comprehensive literature search was conducted across PubMed/MEDLINE, Scopus, Embase, Web of Science, and the Cochrane Library from database inception to August 2026. The search strategy employed combinations of MeSH terms and keywords: ("thermoplastic*" OR "thermoforming" OR "vacuum forming" OR "pressure forming") AND ("pediatric dentistry" OR "children" OR "adolescents" OR "mixed dentition") AND ("mouthguard" OR "splint" OR "retainer" OR "aligner" OR "obturator" OR "feeding plate" OR "nasoalveolar molding" OR "night guard" OR "trauma" OR "cap splint"). Bibliographies of retrieved articles were hand-searched for additional relevant studies.

Inclusion criteria comprised: (1) studies investigating thermoformed appliances in pediatric or adolescent patients; (2) material science studies on dental thermoplastics with relevance to pediatric indications; (3) systematic reviews, meta-analyses, RCTs, prospective/retrospective cohort studies, in vitro studies, and case series; (4) English-language publications. Exclusion criteria included: (1) adult-only populations without pediatric relevance; (2) non-dental applications; (3) editorials, letters, and conference abstracts lacking primary data.

Evidence was graded using the Oxford Centre for Evidence-Based Medicine (OCEBM) 2011 Levels of Evidence [8]. Given the heterogeneity of included studies, formal meta-analysis was not performed; instead, a narrative synthesis was undertaken with critical appraisal of study quality, risk of bias, and clinical applicability.

III. Material Science and Manufacturing

Polymer Composition and Properties

The clinical performance of thermoformed appliances is fundamentally governed by the underlying polymer physics. Table 1 summarizes the key properties of thermoplastic materials commonly employed in pediatric dentistry.

Material	Elastic Modulus T< (MPa)	Glass Transition temperature(°C)	Melting temperature (°C)	Transparency	Intraoral Aging	Primary Pediatric Indications
PETG	2000–2200	80–85	~220	Excellent	Good	Retainers, aligners, splints
EVA	5–100	~20	~90	Excellent	Good	Mouthguards, night guards
PC	2000–2500	~145	~297	Excellent	Poor	Trauma splints, provisional prostheses
PP	~600	~□18	~175	Poor	Good	Temporary appliances
TPU	2200–2500	90–120	150–220	Excellent	Excellent	Clear aligners (multilayer)
Multilayer PU	700–900	~120	~220	Excellent	Good	Clear aligners (Invisalign)

**Based on ISO 10993 cytotoxicity scoring where available*

PETG is an amorphous copolyester widely favored for orthodontic retainers and clear aligners due to its excellent optical clarity (up to 90% light transmittance), favorable thermoforming characteristics, and good chemical resistance [9,10]. Its glass transition temperature of approximately 80–85°C permits reliable softening during standard thermoforming cycles while maintaining dimensional stability at intraoral temperatures [10]. However, thermoforming significantly reduces sheet thickness (mean reduction ~0.10–0.15 mm) and may subtly alter mechanical properties, including elastic modulus and hardness [10,11].

EVA is a soft, flexible copolymer valued for impact absorption. The vinyl acetate content modulates hardness and shock-absorption capacity. EVA is BPA-free, latex-free, and phthalate-free, with established biocompatibility [12]. Its low T_g (~20°C) and melting range (~90°C) necessitate careful thermoforming temperature control to prevent over-softening and excessive thinning. EVA is the material of choice for sports mouthguards and pediatric night guards, though its softness predisposes to rapid wear under heavy occlusal loading [12].

Polycarbonate offers high rigidity and impact resistance, making it suitable for trauma splints requiring structural stiffness. However, PC exhibits poor resistance to intraoral aging, with susceptibility to hydrolysis, surface crazing, and potential bisphenol A (BPA) leaching—considerations that limit its use in long-term pediatric appliances [9,13]. **Polypropylene** provides excellent chemical resistance and fatigue resistance but poor optical clarity, restricting its use primarily to non-esthetic provisional applications [9].

Thermoplastic polyurethanes (TPU) and proprietary multilayer polyurethane systems (e.g., SmartTrack) dominate the clear aligner market. These materials offer a favorable balance of elasticity, resilience, and force transmission over extended wear periods [9,14]. Multilayer constructions optimize stress distribution for complex tooth movements, though their higher cost and proprietary formulations limit in-office fabrication [14].

Biocompatibility and Safety

All commonly used thermoplastic aligner and retainer materials demonstrate acceptable biocompatibility profiles according to ISO 10993 standards. Systematic review evidence indicates that PETG and EVA cause the least gingival irritation, while TPU aligners are preferred for initial comfort [15]. Cytotoxicity assays generally report cell viability □80% under standard extraction conditions; however, mild cytotoxicity (60–70% viability) may appear with harsh extractions, extended soaking periods, or inadequate post-curing of directly printed resins [16]. BPA and related leachables in saliva-like media are typically undetectable or present in the low ng/mL range for conventional thermoformed sheets [16]. Notably, BPA-free PC alternatives may still leach estrogenic compounds [13]. For directly 3D-printed aligners, residual urethane dimethacrylate (UDMA) and incomplete polymerization represent greater safety concerns than thermoformed sheets, emphasizing the importance of optimized post-curing protocols [16].

Thermoforming Techniques

Vacuum thermoforming applies negative pressure (typically 0.6–0.8 bar below atmospheric) to draw a heated thermoplastic sheet over a dental cast. It is technically simple, equipment costs are low, and it remains the most

widely used technique globally [1,5]. Disadvantages include uneven thickness distribution, with pronounced thinning over occlusal eminences and cast peripheries, and suboptimal reproduction of fine surface detail [5,11].
Pressure thermoforming utilizes positive air pressure (typically 4–6 bar) to force the softened sheet onto the cast. This yields superior adaptation, more uniform thickness distribution, reduced occlusal surface thinning, and better reproduction of gingival margins and undercuts [5,11]. For appliances requiring precise fit—such as orthodontic retainers, surgical guides, and trauma splints—pressure thermoforming is preferred despite higher equipment costs [5]. Comparative studies demonstrate that pressure-formed mouthguards retain greater post-thermoforming thickness, particularly at the labial and buccal surfaces, thereby enhancing protective efficacy [17].

Table 2. Comparison of vacuum versus pressure thermoforming

Parameter	Vacuum Thermoforming	Pressure Thermoforming
Pressure differential	Negative (~0.6–0.8 bar)	Positive (~4–6 bar)
Adaptation	Moderate	Superior
Thickness distribution	Uneven; significant thinning	More uniform; less thinning
Surface detail reproduction	Moderate	Excellent
Equipment cost	Low	Moderate–High
Indications	Mouthguards, fluoride trays, splints	Aligners, retainers, surgical guides, splints

Digital Workflows

Contemporary pediatric dentistry increasingly integrates intraoral scanning, computer-aided design (CAD), and additive manufacturing into thermoformed appliance fabrication. Digital workflows eliminate alginate impressions—particularly advantageous for children with gag reflexes or special healthcare needs—and enable rapid model production [18].

Two primary pathways exist: (1) thermoforming over 3D-printed models, and (2) direct 3D printing of aligners. Thermoforming over printed models introduces geometric inaccuracies related to resin thermal behavior during heating; standard dental model resins may deform or release volatiles when subjected to thermoforming temperatures [18]. Studies comparing fused deposition modeling (FDM) and digital light processing (DLP) printed models report no significant dimensional differences from original models, though neither guarantees flawless aligner production [18].

Directly printed aligners (e.g., using Dental LT Resin or TC-85 DAC) eliminate the thermoforming step, potentially improving geometric accuracy and mechanical resistance [18,19]. However, printed aligners exhibit different force-degradation kinetics compared with thermoformed aligners; TC-85 resin maintains more consistent force transmission over time, whereas thermoformed materials demonstrate stress relaxation [19]. Post-curing quality critically determines biocompatibility; insufficient curing elevates residual monomer levels and cytotoxicity [16,18].

For pediatric applications, intraoral scanning accuracy in primary and mixed dentition remains a concern. Erupting teeth, small arch dimensions, and patient movement artifacts can compromise digital model fidelity. Emerging artificial intelligence (AI)-assigned scan segmentation and automated appliance design algorithms may mitigate these challenges, though validation in pediatric cohorts is limited [20].

IV. Clinical Applications

Trauma Management

Dental and maxillofacial trauma accounts for a substantial proportion of pediatric dental emergencies. The growing craniofacial skeleton, with its increased bone elasticity, developing tooth buds, and ongoing growth, necessitates conservative stabilization techniques that minimize iatrogenic damage to developing structures [21].

Cap Splints

Thermoformed cap splints are custom appliances fabricated from rigid thermoplastic sheets (typically 1.0–1.5 mm PETG or PC) adapted over dental casts. These splints partially or completely cover occlusal and coronal surfaces, stabilizing fractured dentoalveolar segments while preserving the developing dentition [21,22].
Compared with conventional acrylic cap splints, thermoformed variants are thinner, lighter, more esthetic, and require fewer laboratory steps. Their transparency facilitates visualization of underlying teeth and soft tissues during follow-up [21]. Primary indications include dentoalveolar fractures, minimally displaced alveolar fractures, and selected mandibular fractures in children. They may also serve as adjuncts to circummandibular wiring when additional stabilization is required [22].
Clinical reports (Level IV evidence) describe successful management of anterior mandibular dentoalveolar fractures in patients aged 4–13 years using pressure-formed splints cemented with glass-ionomer cement [22]. Splinting duration typically ranges from 2–4 weeks. The intimate fit and uniform occlusal force distribution provide adequate immobilization while improving patient comfort and oral hygiene maintenance [21,22].

Limitations: Thermoformed cap splints lack the rigidity of titanium miniplate fixation and are contraindicated for severely displaced, comminuted, or unstable fractures. Their efficacy depends on adequate remaining dentition for retention; primary teeth with short clinical crowns may provide insufficient mechanical resistance. Furthermore, long-term data on growth disturbance, root resorption, or pulp necrosis rates compared with conventional fixation are absent.

Intermaxillary Fixation (IMF)

Traditional IMF using arch bars is associated with prolonged chairside time, gingival trauma, hygiene compromise, and risk of injury to developing permanent tooth buds [21]. Thermoformed IMF splints offer a conservative alternative. Rigid thermoplastic sheets are adapted to both arches and secured via circummandibular wiring, orthodontic ligatures, or elastics after cementation with glass-ionomer luting cement [21].

The precise fit enhances fracture stabilization while minimizing soft tissue irritation. Smooth, transparent surfaces facilitate oral hygiene and periodontal monitoring. Fabrication is relatively rapid and cost-effective, rendering these appliances valuable in emergency settings [21].

Limitations: As with cap splints, thermoformed IMF is reserved for carefully selected cases. It does not provide sufficient rigidity for unstable or comminuted mandibular fractures. Evidence is restricted to case reports and small case series (Level IV); no prospective comparative studies have evaluated healing times, malunion rates, or growth outcomes versus rigid internal fixation.

Orthodontic and Dentofacial Orthopedic Applications

Essix Retainers

Introduced by Sheridan and colleagues in 1993, Essix retainers are vacuum- or pressure-formed removable retainers fabricated from transparent PETG or polypropylene sheets [23]. They have become one of the most widely used retention appliances following orthodontic treatment, attributed to superior esthetics, accurate adaptation, ease of fabrication, and cost-effectiveness [23].

In pediatric dentistry, Essix retainers are indicated following interceptive orthodontic treatment, anterior crossbite correction, space closure, incisor alignment, and minor tooth movement. They may also serve as temporary space maintainers or carriers for adjunctive procedures such as topical fluoride application [23,24].

A randomized controlled trial comparing Essix and Hawley retainers over 1 year of active retention and 2 years of follow-up found that both appliances exhibited similar retention characteristics overall; however, Essix retainers were more effective in maintaining mandibular incisor position during the retention period (Level II evidence) [24]. Patient cooperation was reportedly higher with Essix retainers, likely due to improved comfort and esthetics [24].

Limitations: Essix retainers are susceptible to occlusal wear, discoloration, distortion, and fracture during prolonged use. Complete occlusal coverage may contribute to posterior open bite if worn beyond the prescribed retention period. Regular follow-up and periodic replacement are essential [23,24].

Clear Aligner Therapy in Mixed Dentition

The application of clear aligner therapy (CAT) to pediatric interceptive orthodontics represents one of the most significant expansions of thermoformed sheet technology. Systems such as Invisalign First (Align Technology) are specifically designed for growing patients in mixed dentition, addressing arch expansion, anterior crossbite correction, space management, and eruption guidance [25,26].

A 2025 systematic review and meta-analysis of CAT in adolescent interceptive orthodontics identified eight relevant studies, reporting moderate success in maxillary arch expansion (3.0–3.5 mm), though with substantial heterogeneity (I^2 ~99.9%) [25]. Clear aligners demonstrated predictable transverse expansion and anterior crossbite correction, with high patient and parental satisfaction (85–92%) [25,26]. A scoping review of mixed dentition cases reported effective correction of dentoalveolar issues, though skeletal changes were less pronounced compared with traditional functional appliances such as the Twin Block [26].

Prospective studies using Invisalign First in early mixed dentition (mean age 8–10 years) demonstrated statistically significant maxillary intermolar and intercanine width increases, with greatest expansion at deciduous molar regions [25,27]. However, an RCT comparing clear aligners with rapid maxillary expanders (RME) found that RME produced superior palatal volume increases, indicating that clear aligners may not fully replicate the skeletal effects of conventional expansion appliances [25].

Limitations: CAT in mixed dentition requires excellent patient compliance (22 hours/day wear), which may be challenging in younger children. Erupting dentition necessitates frequent monitoring and refinement scans. Attachment loss, incomplete tracking, and the need for multiple refinement stages increase treatment complexity and cost. Long-term stability data in growing patients are sparse, and no RCTs with sample size justification have compared CAT versus fixed appliances for complex skeletal malocclusions [25,26].

Twin Block Modifications

The Twin Block appliance remains a mainstay for correction of skeletal Class II malocclusion in growing children. Thermoformed modifications utilize transparent occlusal shells or retentive components to improve adaptation while reducing bulk and enhancing esthetics [28].
Preliminary clinical reports suggest improved patient comfort, reduced soft tissue irritation, and enhanced hygiene maintenance with thermoformed modifications [28]. Digital workflows involving intraoral scanning, CAD/CAM design, and thermoforming over 3D-printed models have improved fabrication accuracy [28].
Limitations: Functional orthopedic outcomes depend primarily on mandibular advancement magnitude, appliance design, and compliance rather than the thermoplastic material itself. Available literature on thermoformed Twin Block modifications remains limited to case reports (Level IV). Long-term comparative trials assessing skeletal changes (SNB, ANB, mandibular length) are required before thermoformed modifications can be recommended as routine replacements for conventional acrylic designs [28].

Preventive Applications
Mouthguards
Sports-related orofacial injuries are common among children and adolescents, encompassing enamel fractures, luxation injuries, avulsions, and jaw fractures. The use of properly fitted mouthguards is consistently recommended to reduce injury incidence and severity [29,30].
Custom-made thermoformed mouthguards, fabricated by vacuum or pressure adaptation of EVA sheets over dental casts or digital models, exhibit superior fit, retention, comfort, and shock absorption compared with stock or boil-and-bite alternatives [29,30]. Intimate adaptation ensures even distribution of impact forces, reducing trauma to teeth, periodontal tissues, and supporting structures [30].
The protective efficacy depends on material composition, post-thermoforming thickness, and fabrication technique. International standards, including ASTM F697 and EN 93, specify minimum thickness and impact-resistance requirements. Multilayered EVA mouthguards with adequate post-thermoforming thickness provide enhanced impact absorption compared with thinner single-layer designs [17,30]. A systematic review and meta-analysis confirmed the effectiveness of mouthguards in preventing orofacial injuries across sports activities [30].
Limitations: Thermoformed mouthguards require regular replacement in growing children due to erupting teeth and arch dimensional changes. Excessive thermoforming temperature or inadequate pressure produces non-uniform thinning, compromising protection. Patients with fixed orthodontic appliances require specialized designs to accommodate brackets and wires. Cost and laboratory time exceed those of over-the-counter alternatives.
Night Guards (Occlusal Splints)
Pediatric sleep bruxism is a common parafunctional habit, often self-limiting but occasionally associated with excessive tooth wear, restoration failure, masticatory muscle discomfort, and temporomandibular joint symptoms [31]. Occlusal splints are indicated in selected patients to protect the dentition and redistribute occlusal forces—not to eliminate the habit itself [31].
Thermoformed night guards fabricated from resilient EVA or semi-rigid PETG sheets provide a protective interface between arches. Their minimal bulk, smooth surface, and transparent appearance improve comfort and acceptance in children and adolescents [31].
A systematic review of sleep bruxism treatments in children and adolescents found that occlusal splints and physiotherapy did not produce statistically significant reductions in bruxism symptoms compared with control groups; pharmacotherapy (hydroxyzine/diazepam) and medicinal extracts showed greater efficacy [31]. This underscores that splints serve a protective rather than curative function.
Limitations: Night guards require periodic assessment because material wear, distortion, and ongoing craniofacial growth reduce effectiveness over time. In growing patients, splints may require replacement every 3–6 months. They are contraindicated in patients with untreated caries, periodontal disease, or risk of aspiration with removable appliances.

Craniofacial Rehabilitation
Feeding Plates
Infants with cleft palate frequently experience feeding difficulties due to oronasal communication. Feeding plates obturate the palatal defect, facilitating suckling, reducing nasal regurgitation, and promoting adequate nutritional intake until surgical repair [32].
Traditionally fabricated from acrylic resin, feeding plates can also be constructed from thermoformed thermoplastic sheets. Thermoformed variants offer reduced weight, smooth polished surfaces, improved comfort, rapid fabrication, and simplified laboratory procedures [32]. Digital impressions and 3D-printed models enhance safety and accuracy, particularly in neonates where conventional impressions pose clinical challenges [32].

Limitations: Unlike acrylic feeding plates, thermoformed plates cannot be readily chairside-modified as the infant grows. Their uniform thickness limits the ability to add material for peripheral seal enhancement. Rapid neonatal growth necessitates frequent appliance replacement (every 2–4 weeks), increasing long-term cost.

Nasoalveolar Molding (NAM)

NAM is a presurgical orthopedic technique to reduce alveolar and nasal deformity severity in infants with cleft lip and palate. Conventional NAM appliances are acrylic-based, with soft denture liner selectively added and removed to create negative sculpturing that guides alveolar segment movement [32,33].

Thermoformed sheets have been introduced as alternative NAM materials due to lightweight design, accurate adaptation, and reduced laboratory time [33]. However, a critical distinction exists: conventional acrylic NAM achieves molding through sequential chairside relining with tissue conditioner, whereas thermoformed sheets cannot be predictably bonded to soft lining materials. Instead, negative sculpturing is performed on the working cast or digital model by selectively adding or removing stone; a new thermoformed appliance is fabricated at each treatment stage [33].

This approach offers improved precision and digital workflow compatibility but requires fabrication of a new appliance at each visit. Although it eliminates repeated chairside relining, the cumulative laboratory burden and cost may exceed conventional methods [33].

Limitations: Clinical evidence for thermoformed NAM is restricted to case reports and small case series (Level IV). No prospective studies have compared treatment efficiency, cost-effectiveness, or long-term craniofacial outcomes versus conventional acrylic NAM. The inability to perform chairside modifications limits clinical flexibility.

Obturators

Obturators close congenital or acquired palatal defects, restoring separation between oral and nasal cavities. In pediatric patients, they improve speech, swallowing, and deglutition while reducing nasal regurgitation [32].

Thermoformed obturators provide lightweight, esthetic interim rehabilitation. Their accurate adaptation and smooth surface minimize soft tissue irritation, while transparency facilitates tissue evaluation during follow-up [32]. Digital workflows improve accuracy and reduce laboratory time.

Limitations: Acrylic resin remains preferred for definitive prostheses requiring extensive rigidity or retention. Thermoformed obturators are best suited for interim use or selected pediatric cases with limited defect size. Large defects or insufficient undercut retention may compromise appliance stability.

Restorative and Prosthodontic Applications

Thermoformed sheets serve as matrices for composite resin indices, strip crown templates, and customized restorative guides in pediatric restorative dentistry. Their transparency allows light transmission during polymerization, and precise adaptation ensures anatomically correct restoration contours. Additionally, thermoformed fluoride trays enable customized topical fluoride delivery for high-caries-risk pediatric patients.

Limitations: The thin gauge of thermoformed sheets (typically 0.5–1.0 mm) limits their use to single-surface or small multi-surface restorations. They lack the rigidity required for extensive prosthetic frameworks.

V. Evidence Synthesis and Comparative Outcomes

Table 3. Summary of evidence for thermoformed appliances in pediatric dentistry

Application	Highest Evidence Level	Key Findings	Critical Gaps
Essix retainers	Level II (RCT) [24]	Similar overall retention to Hawley; superior patient satisfaction; better aesthetics	Long-term durability (>5 years); cost-effectiveness
Clear aligners (mixed dentition)	Level II–III (SR, prospective) [25,26]	Effective transverse expansion and crossbite correction; high satisfaction	Skeletal vs. dental effects; long-term stability; RCTs
Mouthguards	Level I (SR/MA) [30]	Effective in reducing orofacial injury incidence and severity	Pediatric-specific impact standards; optimal thickness protocols
Night guards/bruxism	Level I (SR) [31]	Protective function established; no significant reduction in bruxism activity	Growth adaptation protocols; definitive treatment efficacy
Trauma splints (cap/IMF)	Level IV (case series) [22]	Minimally invasive; acceptable in selected fractures	RCTs vs acrylic splints or rigid fixation; growth outcomes
Feeding plates/NAM	Level IV (case reports) [32,33]	Lightweight; rapid fabrication; digital-compatible	Prospective comparative trials; cost-effectiveness; long-term outcomes
Obturators	Level IV (case reports) [32]	Suitable for interim rehabilitation	Comparative studies with acrylic; long-term speech outcomes

Advantages, Limitations, and Contraindications

Advantages
Minimally invasive: Conservative tooth preparation or no preparation required.
Esthetic: Optical clarity and minimal visibility.
Comfort: Reduced bulk and weight compared with acrylic appliances.
Rapid fabrication: Chairside or same-day laboratory turnaround possible with digital workflows.
Biocompatibility: Low irritation potential; BPA-free options available.
Hygiene: Smooth, non-porous surfaces facilitate cleaning.
Limitations
Material degradation: Stress relaxation, water sorption, and thermal cycling reduce mechanical properties over time.
Thickness inconsistency: Vacuum thermoforming produces uneven thinning, compromising strength.
Inability to repair: Thermoformed sheets cannot be reliably repaired or chairside-modified with conventional acrylic resins or liners.
Cost: Digital workflows and pressure-forming equipment require significant capital investment.
Compliance dependence: Removable designs are ineffective without consistent patient cooperation.
Contraindications
• Severe skeletal discrepancies requiring rigid orthopedic correction.
• Unstable or comminuted fractures requiring rigid internal fixation.
• Patients with inadequate dentition for mechanical retention (e.g., severely hypoplastic primary teeth).
• Uncooperative patients or those at risk of appliance aspiration.
Active untreated dental caries or periodontal disease.

VI. Conclusion

Thermoformed thermoplastic sheets represent a transformative technology in pediatric dentistry, offering minimally invasive, esthetic, and patient-specific solutions across trauma management, orthodontics, preventive care, and craniofacial rehabilitation. The evidence base is strongest for orthodontic retainers and mouthguards, where systematic reviews and RCTs support clinical efficacy. Clear aligner therapy in mixed dentition shows considerable promise for interceptive orthodontic applications, though skeletal correction remains modest compared with conventional functional appliances.

For trauma splints, NAM appliances, and obturators, clinical utility is well-described but evidence is predominantly Level IV, precluding definitive treatment guidelines. Material selection must be individualized based on polymer physicochemical properties, anticipated functional demands, and biological safety considerations. Pressure thermoforming and digital workflows enhance precision but introduce new variables requiring careful quality control.

Future research must prioritize prospective comparative studies, standardized thermoforming protocols, and long-term outcome assessments in growing patients. As material science and digital manufacturing continue to converge, thermoformed appliances are poised to become increasingly sophisticated tools in evidence-based pediatric dental practice.

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