Artículo de Revisión

Volumen 16, N° 32. Enero-Junio 2026
Srujana Aravinda y Col.
Pg. 539-564

Acta BIOCLÍNICA
ISSN Electrónico: 3105-403X

DOI:
https://doi.org/10.53766/AcBio/2026.16.32.23

ENHANCING PEDIATRIC DENTAL CARE THROUGH DIGITAL IMPRESSIONS: A CONTEMPORARY PERSPECTIVE

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ABSTRACT

Digital impressions have emerged as a transformative innovation in pediatric dentistry, offering an alternative to traditional impression techniques that often pose challenges in young patients. Intraoral scanners (IOS) provide accurate three-dimensional recordings of dentition without the discomfort associated with conventional materials. They reduce chairside time, enhance patient cooperation, and integrate seamlessly with CAD/CAM systems for efficient appliance fabrication[2]. This review explores the evolution, types, advantages, clinical applications, limitations, and future trends of digital impressions in children. The growing role of digital workflows—augmented by artificial intelligence, 3D printing, and teledentistry—is reshaping pediatric dental care for precision, safety, and child-centered outcomes. Evidence from recent clinical studies underscores the growing acceptance and

Received: 09-12-2025
Accepted: 20-01-2026

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Acta BIOCLÍNICA
ISSN Electrónico: 3105-403X

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https://doi.org/10.53766/AcBio/2026.16.32.23

accuracy of IOS in children, suggesting a shift toward digital-first diagnosis and treatment planning.

KEYWORDS: Pediatric Dentistry; Digital Impressions; Intraoral Scanners; Computer-Aided Design; Computer-Aided Manufacturing; Impression Accuracy; Patient Comfort; Behaviour Management.

MEJORAR LA ATENCIÓN ODONTOLÓGICA PEDIÁTRICA MEDIANTE IMPRESIONES DIGITALES: UNA PERSPECTIVA CONTEMPORÁNEA

RESUMEN

Las impresiones digitales han surgido como una innovación transformadora en la odontología pediátrica, ofreciendo una alternativa a las técnicas de impresión tradicionales que a menudo presentan desafíos en pacientes jóvenes. Los escáneres intraorales (IOS) proporcionan registros tridimensionales precisos de la dentición sin las molestias asociadas con los materiales convencionales. Reducen el tiempo en la consulta, mejoran la cooperación del paciente y se integran perfectamente con los sistemas CAD/CAM para una fabricación eficiente de aparatos[2]. Esta revisión explora la evolución, los tipos, las ventajas, las aplicaciones clínicas, las limitaciones y las tendencias futuras de las impresiones digitales en niños. El creciente papel de los flujos de trabajos digitales, potenciados por la inteligencia artificial, la impresión 3D y la teleodontología, está transformando la atención odontológica pediátrica para lograr precisión, seguridad y resultados centrados en el niño. La evidencia de

Received: 09-12-2025
Accepted: 20-01-2026

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DOI:
https://doi.org/10.53766/AcBio/2026.16.32.23

estudios clínicos recientes subraya la creciente aceptación y precisión de los IOS en niños, lo que sugiere una transición hacia un diagnóstico y una planificación del tratamiento priorizados digitalmente.

PALABRAS CLAVE: Odontología pediátrica; Impresiones digitales; Escáneres intraorales; Diseño asistido por computadora; Fabricación asistida por computadora; Precisión de impresión; Comodidad del paciente; Gestión del comportamiento.

INTRODUCTION

In pediatric dental practice, capturing accurate impressions has long been a challenge due to young patients' limited attention span, strong gag reflexes, and overall discomfort with invasive procedures[1-5]. Traditional materials like alginate and polyvinyl siloxane, while widely used, often trigger anxiety and result in compromised impressions due to movement or lack of cooperation[6]. The advent of digital impressions, particularly through intraoral scanning, has revolutionized this landscape by offering a child-friendly, precise, and efficient alternative[7].

Intraoral scanners utilize optical or laser technology to capture thousands of images per second, producing a real-time, three-dimensional virtual model of the oral cavity[8]. These digital impressions not only provide improved accuracy but also reduce the physical discomfort typically associated with conventional materials[9]. The option to

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Accepted: 20-01-2026

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DOI:
https://doi.org/10.53766/AcBio/2026.16.32.23

pause and later continue scanning without restarting supports the flexibility needed to handle the frequent interruptions that occur during pediatric appointments[10].

Additionally, digital impressions enhance patient engagement by allowing children to view their scan on-screen, often improving compliance and reducing fear[11]. The resulting models can be stored digitally, easily shared with specialists, and used for a variety of diagnostic and therapeutic purposes—including orthodontic planning, appliance fabrication, and preventive care[12]. As pediatric dentistry embraces this digital shift, the focus remains on improving outcomes through patient-centered and technologically advanced solutions[13].

Principles and Clinical Workflow of Digital Impressions

The success of digital impressions in pediatric dentistry depends on the underlying principles of optical image capture, real-time data stitching, and software-guided precision modeling. Unlike conventional impressions, which rely on physical materials to create negative molds, digital impressions generate a virtual 3D model directly from the oral cavity through high-resolution image acquisition[2].

The process typically follows these clinical workflow steps:

1. Pre-scan Preparation

The oral cavity is dried, and soft tissues are retracted using cotton rolls or cheek retractors. Proper isolation enhances

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ISSN Electrónico: 3105-403X

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scanning accuracy and prevents image distortion caused by saliva or movement[21].

2. Intraoral Scanning

Using a handheld wand-like intraoral scanner, the operator captures the upper arch, lower arch, and bite registration. The scanning process typically adheres to a predefined algorithm, beginning at the occlusal surface and proceeding to the buccal side before moving to the lingual aspect[22]. Children benefit from the quick, non-invasive nature of this step, which can be paused and resumed if needed[23].

3. Real-Time Visualization and Error Checking

The scanned images are immediately displayed on a monitor, providing visual feedback to the clinician. Missed or blurry areas are flagged by the software, allowing instant rescanning without starting over[2].

4. Data Optimization and Export

The software stitches the captured images into a single 3D model, correcting for minor movement or noise. The final file is then exported in standard formats like STL (stereolithography), PLY, or OBJ for further use[2].

5. Integration with CAD/CAM or 3D Printing

These files can be used to fabricate restorations, orthodontic appliances, night guards, or custom trays using milling or 3D printing. This integration eliminates the need for physical model pouring and accelerates delivery of care[2].

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6. Storage and Sharing

Digital records are stored in cloud or local databases, easily retrievable for future reference. Files can also be shared with specialists for collaborative planning or remote consultations—an advantage in school dental programs or rural outreach settings[2].

This workflow not only reduces the physical discomfort and chairside time for young patients but also enhances diagnostic accuracy and treatment efficiency. The intuitive nature of the process makes it ideal for use in uncooperative or anxious children, where speed and simplicity are critical[28].

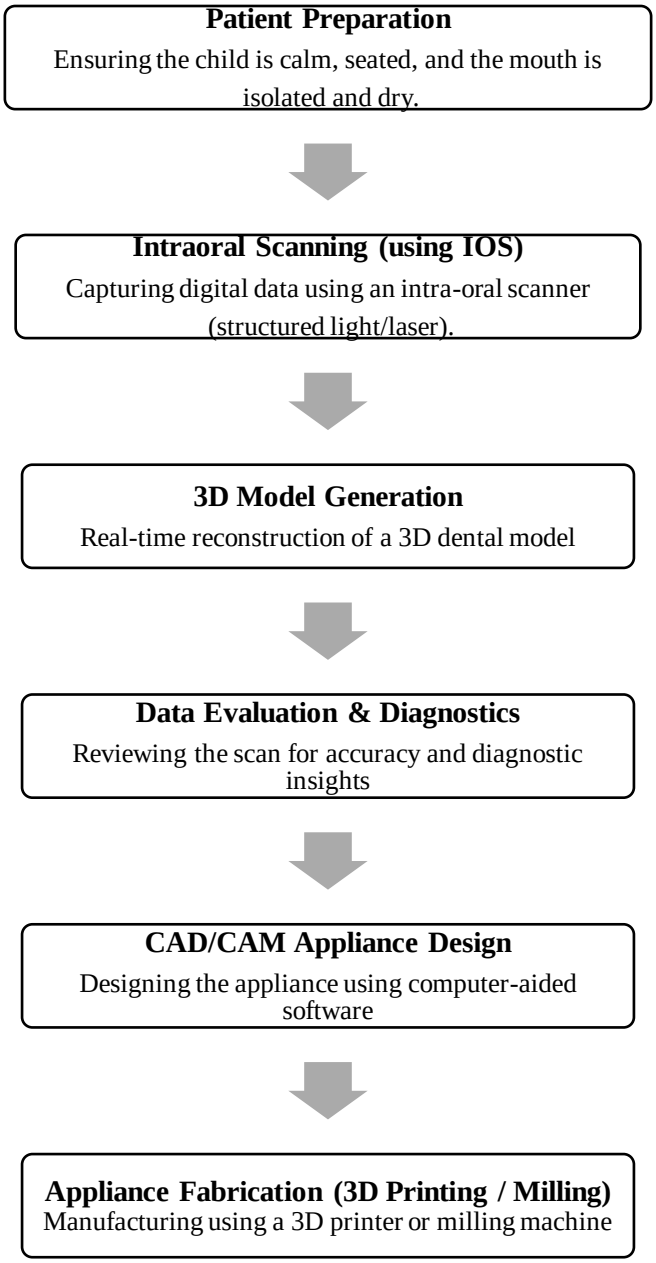
Received: 09-12-2025
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Flowchart 1: Clinical Workflow of Digital Impressions in Pediatric Dentistry

Received: 09-12-2025
Accepted: 20-01-2026

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Advantages of Digital Impressions in Pediatric Dentistry

The adoption of digital impressions in pediatric dental practice offers a wide array of advantages that directly address the unique challenges associated with treating young patients. These benefits span across clinical accuracy, patient comfort, treatment efficiency, and data management, making intraoral scanners a transformative addition to child-centered dental workflows[29].

1. Enhanced Patient Comfort

Digital scanning eliminates the need for impression trays and alginate materials, which are often uncomfortable for children and can trigger gag reflexes[30]. The non-invasive, wand-like design of scanners is less intimidating and better tolerated, especially in anxious or special needs children[31].

2. Reduced Chairside Time

Compared to traditional impressions, digital workflows significantly shorten the time required for impression-taking. This is especially beneficial for children with limited attention spans or those prone to restlessness[32]. The ability to pause and resume scanning allows flexibility during behavioral interruptions[33].

3. Improved Accuracy and Detail

Digital impressions offer high-resolution 3D imaging that reduces errors caused by material distortion, voids, or poor tray seating[34]. Multiple studies have shown that intraoral scanners deliver precision equal to or better than traditional methods,

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DOI:
https://doi.org/10.53766/AcBio/2026.16.32.23

particularly in short-span pediatric prosthetics and orthodontic planning[35].

4. Real-Time Feedback and Re-Scanning

Scanners allow immediate visualization of the scanned area, enabling real-time error detection. In contrast to traditional impressions that must be completely redone if errors occur, digital impressions enable targeted rescanning of specific areas, thereby conserving both time and materials[36].

5. Easier Storage and Record Management

Digital files eliminate the need for physical storage space and reduce the risk of model breakage or misplacement. These virtual records can be stored securely and retrieved instantly for review, fabrication, or legal documentation[37].

6. Seamless Integration with CAD/CAM and 3D Printing

Once captured, digital impressions can be instantly imported into design software to fabricate space maintainers, crowns, night guards, or appliances with minimal turnaround[38]. This enhances workflow speed and reduces the need for multiple appointments.

7. Better Communication and Teledentistry Integration

Digital files can be shared easily with lab technicians, orthodontists, or other specialists, improving interdisciplinary collaboration. This is particularly useful for school screening programs or rural outreach where remote consultations are beneficial[39].

Received: 09-12-2025
Accepted: 20-01-2026

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8. Positive Behavioral Reinforcement

Scanners often display a real-time image of the child's mouth, which can be used as a teaching tool or source of fascination, reinforcing cooperation and reducing anxiety[40].

Parameter	Conventional Impressions	Digital Impressions	Clinical Impact in Pediatrics
Comfort	Low often induces gag reflex	High-non-invasive	Improves child cooperation
Time Efficiency	Longer chairside time	Shorter chairside time	Reduces behavioral fatigue
Accuracy	Prone to distortions	High accuracy with 3D capture	Better fit for appliances
Storage	Requires physical space	Digital file storage	Simplifies record-keeping
Reproducibility	Poor with remakes	Easily reproducible	Fewer repeat appointments
Integration	Limited digital workflow	Seamless CAD/CAM & 3D	Enables faster treatment delivery

Table 2: Comparison between Conventional and Digital Impressions in Pediatric Dentistry

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Accepted: 20-01-2026

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Limitations and Challenges of Digital Impressions in Children

While digital impressions offer significant advantages in pediatric dentistry, several limitations and practical challenges must be acknowledged to ensure their optimal use in clinical practice[41]. These factors are especially relevant when treating children with behavioral, anatomical, or systemic complexities.

1. Cost of Equipment and Maintenance

Intraoral scanners involve a high initial investment, with ongoing costs for software updates, calibration, and potential repairs[42]. For smaller clinics or community health centers, this can be a limiting factor, especially if the patient load is insufficient to justify the expense[43].

2. Learning Curve for Clinicians and Staff

Though user-friendly, digital scanning systems require a certain degree of training for effective use. Misuse or unfamiliarity with scanning protocols can result in inaccurate models or wasted clinical time[44]. Pediatric dentists must also learn to scan quickly and effectively in often unpredictable patient behavior scenarios.

3. Moisture and Saliva Management

Children often have poor salivary control, which can interfere with the scanning process[45]. Moisture can distort images or prevent the scanner from capturing fine surface details. Ensuring adequate field isolation in young, uncooperative patients remains a key challenge during scanning[46].

Received: 09-12-2025
Accepted: 20-01-2026

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4. Limited Use in Certain Clinical Scenarios

Digital impressions may struggle in cases with deep subgingival margins, mobile teeth, or crowded arches, which are common in mixed dentition[47]. Moreover, partially erupted or missing teeth may create scan gaps, requiring clinician adjustments or supplemental conventional methods[48].

5. Software Compatibility and File Handling

Although most modern scanners offer open file formats (like STL), some systems may have proprietary software that restricts integration with third-party design platforms or 3D printers[49]. This can reduce flexibility and increase dependence on specific workflows.

6. Patient Movement and Limited Cooperation

Children who are fearful, uncooperative, or have special healthcare needs may resist the scanner, especially during initial appointments[50]. Although scanning is quicker than traditional impressions, it still requires steady movement and focus from the child.

7. Technical Malfunctions and Downtime

Like any digital device, scanners are subject to errors, connectivity issues, or software glitches[51]. If issues arise during scanning, especially in a busy pediatric practice, treatment delays or rescheduling may occur.

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8. Not Universally Reimbursed

In some regions, digital impression procedures are not reimbursed at the same rate as traditional methods, affecting their adoption in government or insurance-based practices[52].

Despite these limitations, growing evidence and clinical experience suggest that with proper training, workflow optimization, and behavior management, most of these challenges can be successfully overcome, allowing digital impressions to be a standard part of pediatric dental care[53].

Applications of Digital Impressions in Pediatric Dentistry

Digital impressions have rapidly expanded their role in pediatric dental care, finding applications across diagnostic, preventive, restorative, and orthodontic domains. Their ability to produce highly accurate, child-friendly, and efficient virtual models supports a range of clinical procedures tailored to young patients[54].

1. Space Maintainers and Habit-Breaking Appliances

Digital impressions enable precise fabrication of passive and active appliances, such as space maintainers and thumb-sucking deterrents. These devices can be designed virtually and produced using CAD/CAM or 3D printing, minimizing adjustment appointments and improving fit[55].

2. Pediatric Crowns and Restorations

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Intraoral scanners assist in capturing the anatomy of decayed or prepared primary teeth for accurate fabrication of esthetic crowns. Materials like zirconia can be shaped using milled restorations based on digital impressions, offering better marginal integrity and esthetics[56].

3. Interceptive Orthodontics

Digital models allow for the planning and monitoring of early malocclusions, crossbites, and crowding in mixed dentition. They aid in designing removable orthodontic appliances and provide a baseline for growth tracking over time[57].

4. Monitoring Eruption and Growth

Sequential scans can track tooth eruption, arch development, and craniofacial growth, especially valuable for children with syndromic conditions or cleft anomalies. These records serve as a non-invasive monitoring tool without repeated radiographs[58].

5. Trauma and Forensic Documentation

In cases of dental trauma, digital impressions offer a reliable way to document pre- and post-injury occlusion, fractures, or tooth displacement. These records may serve medico-legal purposes and support forensic identification if needed[59].

6. Behavioral and Educational Uses

Displaying intraoral scans in real time captures the attention of both children and parents by showing plaque, caries, and tooth alignment. This visual approach supports oral hygiene education and may

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enhance adherence to preventive measures[60].

7. Prosthetic Planning in Pediatric Patients with Hypodontia or Anodontia

Children with developmental dental anomalies benefit from digital scans that allow for the design of partial dentures or interim prostheses that are lightweight and quickly fabricated[61].

8. Preventive Sealants and Resin Infiltration

Scans can be used to identify early non-cavitated lesions and aid in planning preventive sealant placement or resin infiltration techniques, especially in high caries-risk children[62].

Overall, the versatility of digital impressions in pediatric dentistry makes them a core part of modern preventive, interceptive, and restorative approaches, while also reducing anxiety and chairside time[63].

Future Trends in Digital Impressions in Pediatric Dentistry

As digital technology continues to evolve, the role of intraoral scanning in pediatric dentistry is poised for significant transformation. Incorporating artificial intelligence (AI), cloud storage, virtual reality (VR), and teledentistry is anticipated to expand capabilities, accelerate processes, and make digital workflows more child-friendly[64].

1. Artificial Intelligence and Automated Diagnostics

Future scanners will increasingly incorporate AI algorithms to automatically detect carious lesions, anatomical

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landmarks, or occlusal interferences during the scanning process[65]. In pediatric practice, this reduces clinician dependency on post-scan evaluation and improves early detection of developmental abnormalities.

2. Chairside Appliance Fabrication

With the integration of compact 3D printers and chairside milling units, appliances like space maintainers or crowns can be fabricated within a single visit[66]. This minimizes recall appointments, especially useful in school dental programs or rural outreach initiatives.

3. Cloud-Based Record Systems and Big Data

Scans stored in cloud platforms will allow longitudinal comparison of growth, eruption, and treatment outcomes in children. Aggregated data may be used to create normative pediatric dental models, improving diagnostic accuracy for clinicians worldwide[67].

4. Virtual Reality (VR) Integration for Behavioral Management

Future systems may combine scanning with VR environments to distract or engage children during procedures, reducing anxiety and enhancing compliance[68]. This aligns with pediatric behavioral guidance strategies and minimizes the need for sedation in some cases.

5. Teledentistry and Mobile Scanning Units

Portable scanners connected via telehealth platforms will allow pediatric dentists to assess children in remote schools or rural clinics, transmitting scans in real time to

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specialists for collaborative diagnosis and planning[69]. This improves access to care and supports early intervention.

6. Integration with Growth Prediction Software

Digital models may soon integrate with AI-powered growth forecasting software to simulate future dental arch development, aiding in preventive and interceptive orthodontics[70]. This holds promise for personalized pediatric treatment planning.

7. Eco-Friendly Digital Workflows

As awareness of environmental sustainability grows, digital impressions reduce reliance on disposable trays, alginate, and shipping of physical models, contributing to greener dental practices[71].

These innovations will further solidify the role of digital impressions in shaping a minimally invasive, preventive, and precision-based approach to pediatric oral health. The synergy between technology and child-centered care will likely define the next era of pedodontics.

Conclusion

Digital impressions have significantly advanced the practice of pediatric dentistry by offering a more precise, efficient, and child-friendly alternative to traditional impression techniques. Intraoral scanners eliminate the discomfort and anxiety associated with impression trays, allowing faster and more accurate workflows that are especially beneficial in treating children. Their integration with CAD/CAM systems

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and 3D printing has transformed how appliances, crowns, and diagnostic models are created—enhancing both clinical outcomes and patient satisfaction.

Despite certain limitations such as cost, technique sensitivity, and the need for field isolation, ongoing technological progress is rapidly addressing these concerns. The advent of artificial intelligence, cloud platforms, and mobile scanning technologies is broadening the applications of digital impressions in preventive, interceptive, and emergency pediatric dentistry.

As the dental profession shifts toward a digital-first approach, the use of digital impressions in children is no longer a novelty but a necessity for modern, high-quality pediatric dental care. By embracing these innovations, clinicians can provide more accurate, comfortable, and efficient care—laying a strong foundation for lifelong oral health in the youngest members of society.

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Received: 09-12-2025
Accepted: 20-01-2026

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