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Feasibility of a Hologram-Assisted Dietary Education Intervention Among Children with Autism Spectrum Disorder: A Pre–Post Study

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Highlights

What are the main findings?

- Hologram-assisted dietary education was feasible to deliver to participating children with autism spectrum disorder.
- Dietary classification scores were higher and task-completion time was shorter following the educational session.

What is the implication of the main finding?

- Hologram-assisted learning may offer an innovative, visually engaging approach to preventive oral-health education tailored to children with autism spectrum disorder.
- The study findings support further controlled evaluation of hologram-assisted technology as an educational tool in paediatric dentistry.

Abstract

Background: Children with autism spectrum disorder (ASD) experience substantial oral health challenges associated with behavioural, sensory, and dietary factors. Technology-assisted preventive dietary education tailored to neurodiverse learners remains underdeveloped. **Aim:** Our objectives were to assess the feasibility of a hologram-assisted dietary education intervention among children with ASD, examine preliminary changes in oral health-related dietary classification performance and task-completion time, and assess satisfaction with the classification activity. **Methods:** A single-group pre–post feasibility study recruited children from schools offering educational inclusion programmes for children with ASD in Al-Ahsa between February and May 2026. Participants completed gamified hologram-based food-classification tasks before and directly after a group hologram-assisted dietary education session. Feasibility indicators were recruitment and paired-assessment completion; satisfaction with the classification activity was also assessed. Preliminary participant-level outcomes were classification score and task-completion time. **Results:** Of 75 invited children, 40 enrolled (53.3%), and 38 provided valid paired data (95.0%). Mean classification score increased from 9.99 ± 1.94 to 10.71 ± 1.89 ($p = 0.011$). Mean task-completion time decreased by 19.81 s (95% CI 11.71–27.90; $p < 0.001$). Satisfaction was high at both assessments (median [IQR], 5 (3–5) versus 5 (4–5); $p = 0.004$). **Conclusions:** The findings support the feasibility of delivering hologram-assisted dietary education to participating children with ASD. Dietary classification scores were higher and task-completion time was shorter following the session, while satisfaction with the classification activity

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remained high. Controlled studies with longer follow-up are needed to assess effectiveness and durability.

Keywords: autism spectrum disorder; dietary education; feasibility study; holographic learning; oral health education; preventive dentistry; special education

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterised by persistent deficits in social communication and interaction alongside restricted and repetitive behaviours [1]. Children with ASD often experience sensory sensitivities, behavioural rigidity, and communication challenges [2]. These factors may create substantial barriers to oral hygiene practices and dental care contributing to heightened anxiety, discomfort, and avoidance of dental treatment [3].

Children with ASD are disproportionately affected by oral health problems. Evidence from Saudi Arabia indicates a higher prevalence of dental caries, greater gingival inflammation, increased risk of dental trauma, and poorer oral health-related quality of life compared with neurotypical peers [4]. These findings align with international evidence demonstrating the high prevalence of dental caries and periodontal disease among individuals with ASD [5] as well as greater caries severity relative to non-ASD populations [6]. Dietary sugar exposure and difficulties maintaining effective oral hygiene may contribute to the reported burden of dental caries and gingival inflammation among children with ASD [4–7]. Collectively, this evidence highlights the significant burden of oral disease among children with ASD and underscores the importance of preventive oral health strategies.

Oral-health interventions for children with ASD have focused largely on oral hygiene and cooperation with dental care, with comparatively limited evaluation of dietary education [8–11]. Children with ASD may experience food selectivity, with reported dietary patterns including increased intakes of sweet and starchy foods and decreased intakes of vegetables and fruits [12,13]. These findings strengthen the rationale for oral-health-related dietary education. Current paediatric dietary guidance promotes well-balanced, nutrient-dense diets and recommends limiting frequent exposure to sugar-containing foods and drinks to reduce caries risk [14].

Emerging immersive technologies, including virtual reality and holographic educational systems, may offer new opportunities for interactive educational experiences [15–17]. A meta-analysis of educational studies reported improved student learning performance with 3D holographic technology [18]. Structured visual supports have shown potential for improving oral hygiene practices and cooperation with dental care among children with ASD [8,9]. Hologram-assisted education may therefore be relevant by presenting information in a structured, visually reinforced format that supplements verbal instruction. Although immersive technologies involving individuals with ASD have primarily been explored in social and behavioural training contexts [19], holographic technology for preventive oral health education in this population remains largely unexplored.

To our knowledge, this is the first study to evaluate the feasibility, satisfaction with the classification activity, and preliminary educational outcomes of a hologram-assisted dietary education intervention among children with ASD. Accordingly, we aimed to assess the intervention's feasibility and participants' satisfaction with the classification activity and examine preliminary changes in oral health-related dietary classification performance and task-completion time.

2. Methods

2.1. Study Design

We conducted a single-group pre–post feasibility study. The description of the intervention was guided by the Template for Intervention Description and Replication checklist and guide [20].

We obtained ethical approval from the Institutional Review Board of King Faisal University (approval no. KFU-REC-2025-SEP-ETHIC S3485) and permission to conduct the study from the Planning and Development Department of the General Directorate of Education in Al-Ahsa, Saudi Arabia. Written informed consent was obtained from a parent or legal guardian of each participant before participation.

We assigned coded identifiers to participant records and excluded identifying information, including school names, from the research dataset and study reports.

2.2. Setting and Participants

The study was conducted at a hologram-based educational facility at King Faisal University. Children were recruited from schools offering educational inclusion programmes for children with ASD in Al-Ahsa from 10 February to 5 May 2026. Forty children with ASD were enrolled.

Children from each school attended the facility separately. Children arrived in organised groups accompanied by their teachers, who remained present throughout the study session.

Before data collection, the research team visited participating schools to become familiar with the children's communication styles, behavioural characteristics, and individual support needs and to familiarise the children with the research team before the university-based session. This preparatory approach is consistent with recommendations for research involving children and neurodiverse populations [21].

Invitation packs containing study information and a parental consent form were distributed to all eligible children in the participating schools through their teachers. Parents were asked to review the study information and return the signed consent form in the child's school bag. Teachers reminded parents to return the forms, which were subsequently collected from the teachers by the research team. After completing the study procedures, each child received a small appreciation pack containing toothpaste and an age-appropriate toothbrush together with milk and a banana.

2.3. Eligibility Criteria

Special education teachers confirmed each child's enrolment in educational inclusion programmes serving children with ASD and advised whether the child was expected to follow the instructions and participate in the visual classification activity. Task eligibility was based on teachers' judgement rather than a standardised assessment. The institution-level recruitment exclusion and individual eligibility and discontinuation criteria are summarised in Table 1.

Table 1. Participant eligibility and discontinuation criteria.

Category	Criterion
Institution-level exclusion before recruitment	One specialised autism institute serving 35 children with ASD was excluded before recruitment based on special education teachers' advice that the children were expected to require extensive support to complete the planned visual classification task.

Table 1. *Cont.*

Category	Criterion
Inclusion	Enrolment in an educational inclusion programme for children with ASD, as confirmed by the child's teacher. Expected ability to follow the instructions and participate in the visual classification activity, based on teachers' judgement.
Exclusion or discontinuation	Inability to complete the baseline assessment, or distress that prevented continued participation.

2.4. Outcomes

Feasibility indicators were recruitment and paired-assessment completion; satisfaction with the classification activity was also assessed. Recruitment was defined as the proportion of invited children who enrolled. Paired-assessment completion was defined as the proportion of enrolled participants who provided valid baseline and post-intervention outcome data according to the study protocol. Satisfaction with the classification activity was assessed at baseline and post-intervention. Preliminary participant-level outcomes were changes in oral health-related dietary classification score and task-completion time from baseline to post-intervention.

2.5. Gamified Hologram-Based Matching and Classification Task

Dietary classification performance was evaluated using a structured gamified hologram-based matching and classification task presented through an enclosed holographic display box (Figure 1A).

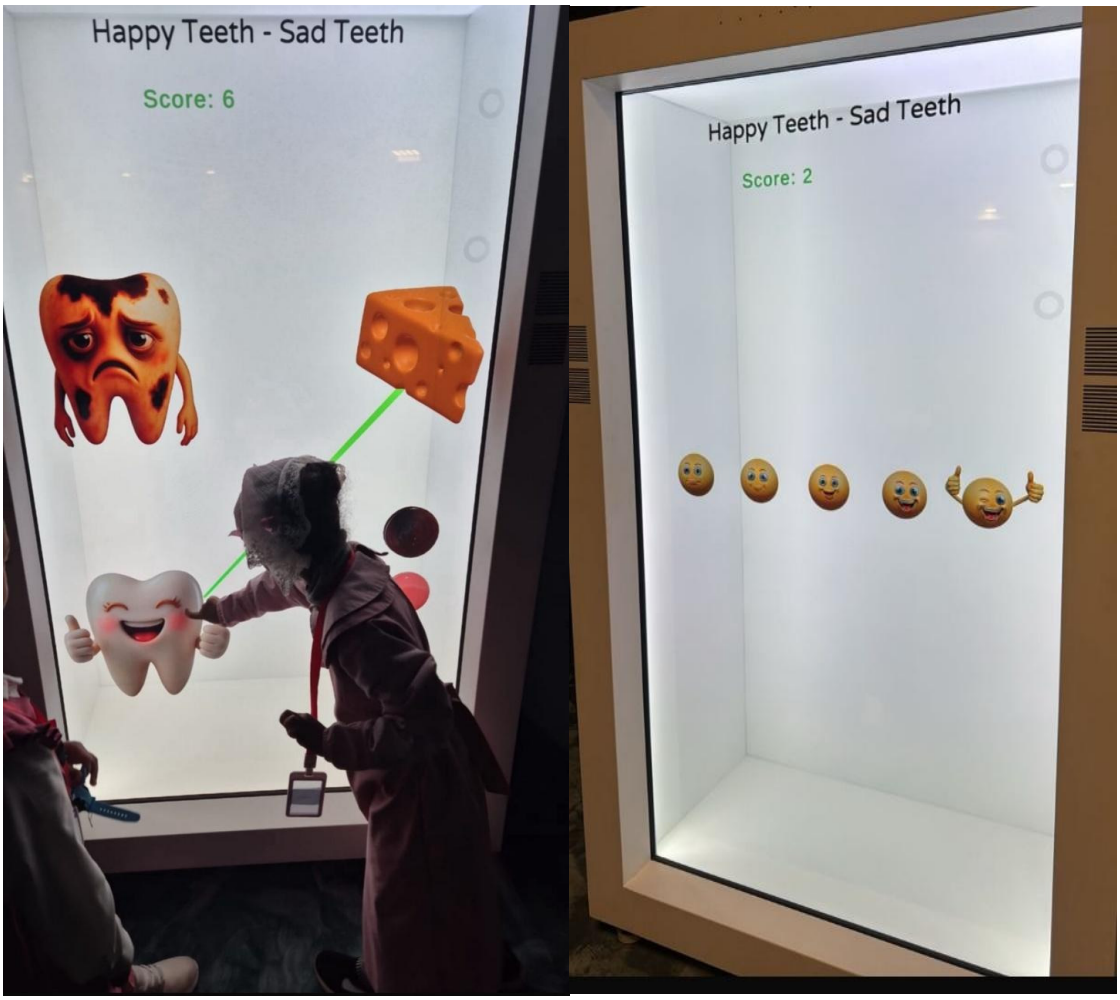
The box provided an individual, low-distraction environment. The display presented two categories: 'happy teeth' (tooth-friendly) and 'sad teeth' (tooth-unfriendly). Each category was represented by animated tooth icons positioned on opposite sides of the display.

Food and drink items were presented sequentially. For each item, the child decided whether it belonged to the 'happy teeth' or 'sad teeth' category and indicated their choice by using the system interface inside the box.

The interface generated a cumulative score from registered touch inputs. In both assessments, the score was displayed only after completion of the classification task and was not visible during item responses. Children could see the score at task completion, although its meaning was not explained to them. No feedback regarding response accuracy was provided by the researcher during either assessment. The researcher clarified task instructions when necessary, without indicating the correct response.

The task consisted of 12 items, yielding a total score ranging from 0–12. Task completion time was recorded in seconds.

To reduce simple recall effects, the order of item presentation was varied. The baseline and post-intervention assessments each contained 12 items, with the same balance of tooth-friendly and tooth-harming items. We replaced four baseline items at the post-intervention assessment: carrot with broccoli, apple with banana, cupcake with cake, and cookies with a biscuit. Each replacement belonged to the same food group and intended oral-health classification as the corresponding baseline item. The remaining eight items were retained. The complete item lists are provided in Table 2. Equivalent difficulty between the two assessments was not formally evaluated. The enclosed design was intended to minimise external distraction and support engagement among children with ASD.



(**A**) (**B**)

Figure 1. (**A**) Gamified hologram-based matching and classification task used for dietary categorisation and participant interaction. (**B**) Integrated hologram-based satisfaction assessment interface using the Five Degrees of Happiness Smiley Face Likert Scale.

Table 2. Baseline and post-intervention classification items.

No.	Baseline Item	Post-Intervention Item	Intended Classification
1	Cheese	Cheese	Tooth-friendly
2	Milk	Milk	Tooth-friendly
3	Yoghurt	Yoghurt	Tooth-friendly
4	Water	Water	Tooth-friendly
5	**Carrot**	**Broccoli**	Tooth-friendly
6	**Apple**	**Banana**	Tooth-friendly
7	Candy	Candy	Tooth-harming
8	Soft drink	Soft drink	Tooth-harming
9	Sweetened juice	Sweetened juice	Tooth-harming
10	Flavoured milk	Flavoured milk	Tooth-harming
11	**Cupcake**	**Cake**	Tooth-harming
12	**Cookies**	**Biscuit**	Tooth-harming

Note: Replacement items are shown in bold.

2.6. Hologram-Assisted Educational Intervention

Following the baseline assessment, children attended a standardised, scripted hologram-assisted dietary education session (Figure 2).



Figure 2. Hologram-assisted educational session demonstrating immersive visual dietary education delivery.

The intervention used a large-scale holographic projection to show three presenters, tooth icons representing 'happy' and 'sad' teeth, and the selected food and drink items.

The educational content covered 12 food and beverage types. Six tooth-friendly items (cheese, milk, yoghurt, water, fresh vegetables, and fresh fruits) and six tooth-harming items (candy, soft drinks, sweetened juices, flavoured milk, cake, and cookies) were presented. The presentation used food and drink images, including composite images containing multiple examples of broader food groups, alongside either a smiling or sad tooth icon. Simple auditory cues (a 'ding' for tooth-friendly items and a 'buzz' for tooth-harming items) reinforced the classification message. Selection and classification of the items were guided by the American Academy of Pediatric Dentistry dietary recommendations for children and adolescents [14].

The intervention was delivered as a single standardised group-based session entitled 'Happy Teeth vs. Sad Teeth' that lasted 5 min. It was scripted in child-friendly Arabic and delivered through the HoLoTech holographic facility at King Faisal University. Three dental practitioners, all final-year students in the Master of Dental Public Health program at King Faisal University, recorded the holographic presentation in advance with predefined roles. Their preparation included reviewing and rehearsing the standardised script, presenter roles, and session sequence. The first presenter introduced the concepts of 'happy' and 'sad' teeth and returned to conclude the session, the second presented the tooth-friendly foods, and the third presented the tooth-harming foods. During each session, a member of the research team operated the holographic system and played the same pre-recorded presentation. All groups therefore received identical content, sequence, visual materials, auditory cues, and presenter roles, with no individual tailoring. Before the main study, the session was piloted with a small group of children to assess clarity, age appropriateness, and timing. An English translation of the Arabic intervention script is provided as Supplementary Materials S1. Children were observed throughout the session by the research team and accompanying teachers, and participation could be paused or discontinued if distress occurred. No standardised sensory assessment was used.

2.7. Study Procedure

1. Baseline assessment using the gamified hologram-based matching and classification task.
2. Standardised hologram-assisted dietary education session ('Happy Teeth vs. Sad Teeth').
3. Post-intervention assessment using a gamified hologram-based matching and classification task.

No feedback regarding response accuracy was provided by the researcher during either assessment.

2.8. Satisfaction Assessment

Children's satisfaction with the classification activity was assessed using the Five Degrees of Happiness Smiley Face Likert Scale [22]. Figure 1B shows the integrated satisfaction interface.

The scale was integrated into the hologram box interface and consisted of five emoji faces representing increasing levels of happiness (scores 1–5). Satisfaction was measured at two time points: immediately after completion of the baseline classification task and immediately after completion of the post-intervention classification task.

At each time point, children responded to the same question: 'How much did you like playing this game?'

Children selected the face that best represented their experience by interacting directly with the interface.

2.9. Reliability

Three examiners independently observed the same baseline and post-intervention assessments, scored each child's classification responses and recorded task-completion time on separate forms. Examiner-derived scores and completion times were averaged separately for each child at each assessment, yielding one value per outcome for analysis. Interrater reliability was assessed using a two-way mixed-effects absolute-agreement intraclass correlation coefficient (ICC) model for the classification score and task completion time and weighted kappa statistics for satisfaction ratings. Interrater agreement was excellent for classification scores (ICC 0.953–0.968), good to excellent for completion time (ICC 0.886–0.976), and almost perfect for satisfaction ratings (weighted κ 0.917–0.980), supporting the use of aggregated child-level values in subsequent analyses (Table 3).

Table 3. Interrater reliability for classification score, task completion time, and satisfaction rating.

Outcome	Reliability Measure	Estimate
Classification score	ICC	0.953–0.968
Task Completion time	ICC	0.886–0.976
Satisfaction rating	Weighted κ	0.917–0.980

2.10. Sample Size Justification

Because this was a feasibility study, the primary objective was to assess feasibility, satisfaction with the classification activity, and preliminary changes in classification performance and task-completion time rather than to establish definitive effectiveness. Therefore, an a priori hypothesis-testing power calculation was not conducted. Instead, the target sample size of approximately 31–40 participants was informed by practical considerations regarding the recruitment of children with ASD and by comparable autism-related visual

pedagogy research [23]. Sample-size decisions in behavioural research involve balancing statistical requirements with practical and ethical constraints [24].

2.11. Statistical Analysis

Descriptive statistics were calculated for all study variables. Continuous variables were summarized using means and standard deviations, ordinal variables using medians and interquartile ranges, and categorical variables using frequencies and percentages. Pre–post differences in dietary classification scores and satisfaction ratings were assessed using the Wilcoxon signed-rank test, whereas task-completion times were compared using a paired-samples *t*-test. All analyses included the 38 participants with valid paired assessments. Tests were two-sided, with statistical significance set at $p < 0.05$. Given the feasibility design, emphasis was placed on the direction and magnitude of observed changes alongside the results of hypothesis tests. Analyses were performed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA).

3. Results

Of 75 children invited from participating schools, 40 enrolled in the study (a 53.3% recruitment rate). Thirty-five invited children did not enrol because written parental consent was not obtained or they were absent from the scheduled assessment session. One participant had missing post-intervention outcome data, and one post-intervention assessment was invalid because the participant was too fatigued to complete it under the intended protocol. Consequently, 38 participants contributed valid paired data and were included in the primary pre–post analysis corresponding to a valid paired-assessment rate of 95.0% (38/40) (Figure 3). The mean age of the analytical sample was 9.50 ± 2.04 years; 84.2% of participants were male, and 15.8% were female. No sensory distress was observed during the intervention, and no child required a pause or discontinued participation because of sensory distress.

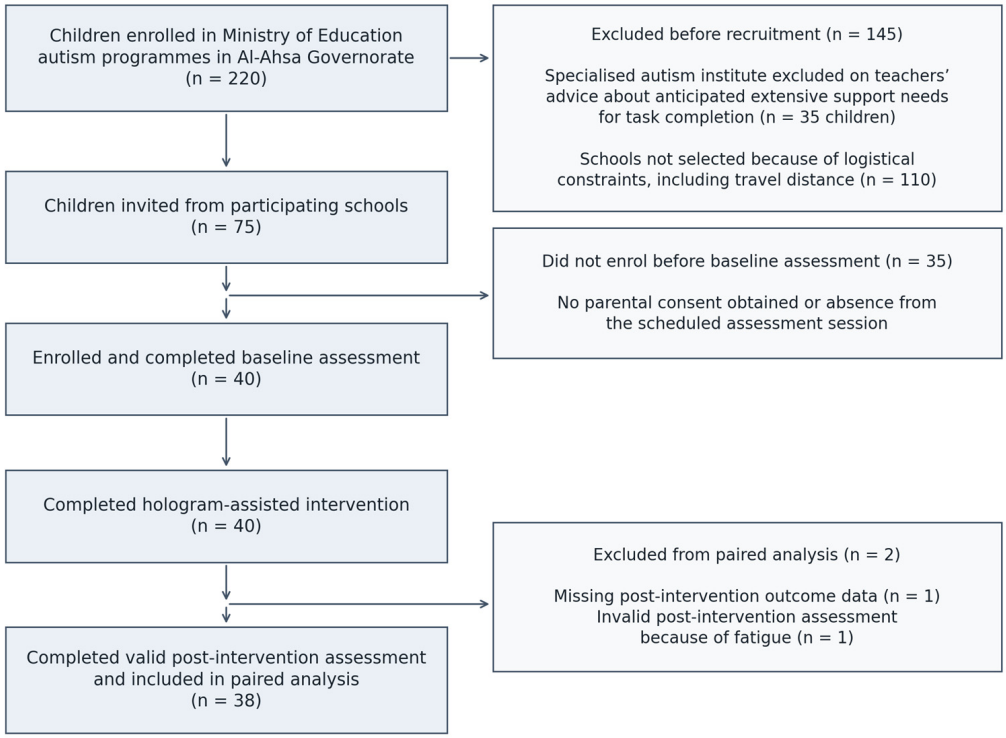
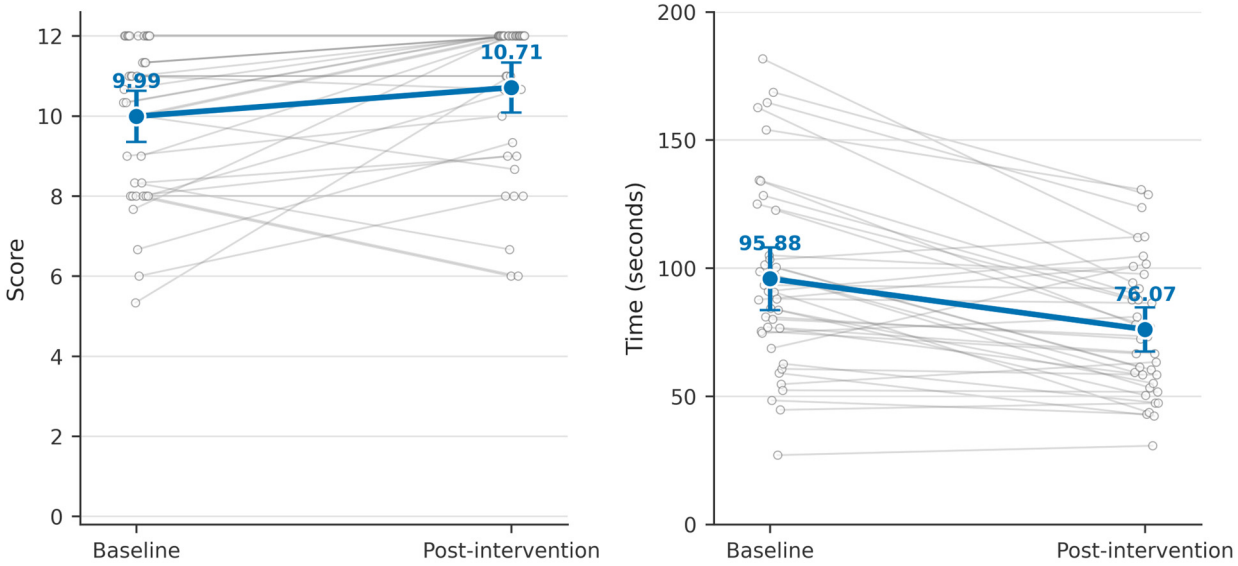


Figure 3. Participant flow through the study.

The mean classification score increased from 9.99 ± 1.94 at baseline to 10.71 ± 1.89 post-intervention. The Wilcoxon signed-rank test indicated a statistically significant change ($Z = -2.546$, $p = 0.011$). Eighteen children had higher post-intervention scores, five had lower scores, and 15 showed no change. The mean task completion time decreased from 95.88 ± 37.19 s at baseline to 76.07 ± 26.15 s post-intervention. The mean reduction was 19.81 s (95% CI, 11.71–27.90; $t(37) = 4.956$, $p < 0.001$). Thirty children completed the task more quickly post-intervention, whereas eight took longer. Figure 4 presents individual participant trajectories and group means with 95% confidence intervals.



(**A**) dietary classification score (**B**) Task completion time

Figure 4. Individual pre–post trajectories following the hologram-assisted dietary education intervention. (**A**) Dietary classification score (possible range 0–12) and (**B**) task-completion time in seconds. Thin grey lines connect each participant's aggregated baseline and post-intervention observations (n = 38). Blue circles and connecting lines represent group means; error bars represent 95% confidence intervals for the mean at each assessment. Individual observations were slightly offset horizontally to reduce overplotting.

Participant-reported satisfaction with the classification activity was high at both assessments, with a median of 5 (IQR 3–5) at baseline and 5 (IQR 4–5) post-intervention. The distribution shifted toward higher satisfaction ratings ($Z = -2.861$, $p = 0.004$).

4. Discussion

This feasibility study found that the hologram-assisted dietary education intervention was feasible to deliver to participating children with ASD. Following the intervention, dietary classification performance improved, task-completion time decreased by approximately 20 s, and satisfaction remained consistently high.

At the participant level, classification scores increased in 18 children, remained unchanged in 15, and decreased in five. Given the brief intervention and feasibility design, the observed mean improvement represents a preliminary educational signal that warrants further investigation. Task-completion time decreased in 30 of 38 participants, suggesting improved task efficiency or familiarity following the intervention.

Satisfaction was high at both assessments, with post-intervention ratings becoming more consistently concentrated at the upper end of the scale.

Our findings are consistent with previous research supporting visual and technology-assisted oral health education for individuals with ASD [23,25–27]. A recent systematic

review showed that immersive technologies can support oral health knowledge, attitudes, self-efficacy, and oral health-related behaviours [28]. Technology-assisted and game-based educational approaches have also shown promise across broader learning and functional outcomes among autistic children [29–31]. Preliminary research has also demonstrated that nonspeaking autistic adolescents and adults can interact successfully with a holographic augmented-reality interface, although sensory tolerance varied among participants [32]. Holographic visualisation has been evaluated in dental education, including endodontic training among dental students [33]. The present study extends this emerging work by applying hologram-assisted delivery to preventive dietary oral-health education for children with ASD.

Informal teacher feedback suggested strong engagement and perceived improvement in children's ability to distinguish between healthy and unhealthy foods. These observations should be interpreted as contextual only because they were not collected using a structured qualitative methodology.

The intervention incorporated repetition, visual reinforcement, predictable categorisation, and a structured learning environment. These characteristics may have supported participant engagement and completion.

Strengths of this study include using a structured intervention protocol, independent outcome recording by three trained examiners with high inter-rater reliability, child-level aggregation of examiner measurements, and implementation in a real-world educational setting involving children with ASD. These findings provide an empirical foundation for larger controlled studies evaluating the effectiveness and longer-term sustainability of hologram-assisted preventive oral health education.

Several limitations should be acknowledged. The lack of a control group and the absence of follow-up beyond the study session limit causal interpretation and conclusions about longer-term retention. Overlapping assessment content may have introduced practice or recall effects. Equivalent difficulty between the assessments was not established. The high baseline classification scores suggest a possible ceiling effect, which may have limited the scope for improvement. Cognitive status, verbal ability and ASD support levels were not systematically recorded; this, together with the exclusion of a specialised autism institute and geographically distant schools, may limit the generalisability of the findings to the wider population of children with ASD. Further controlled studies with larger samples, longer follow-up periods, and validated behavioural outcome measures are required to evaluate the effectiveness, durability, and broader applicability of hologram-assisted preventive oral-health education for children with ASD.

5. Conclusions

The hologram-assisted dietary education intervention was feasible to deliver to participating children with ASD. Higher dietary classification scores and shorter task-completion times were observed following the intervention, and satisfaction with the classification activity remained high. Further controlled studies with longer follow-up are needed to assess sustained changes in dietary behaviour and clinical oral health outcomes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/children13111527/s1, Supplementary Materials S1: English Translation of the Standardised "Happy Teeth vs. Sad Teeth" Intervention Script Delivered in Arabic.

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Informed Consent Statement: The authors obtained written informed consent from the parents or legal guardians of all participants involved in the study.

Data Availability Statement: The data presented in this study are available on reasonable request from the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest.

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