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Effectiveness of guided imagery and neuro-linguistic programming for reducing dental anxiety in children aged 6–13 years undergoing local anaesthesia: A randomised clinical trial

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Highlights

Guided imagery and neuro-linguistic programming are effective non-pharmacological methods to reduce dental anxiety in children.

Neuro-linguistic programming worked across all ages, while guided imagery was most effective for younger children aged 6–9 years.

These methods may reduce sedation use, improve cooperation, and promote positive dental experiences.

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Abstract

Aim: This study aimed to compare the effectiveness of GI, NLP, and conventional behavioural management techniques in reducing dental anxiety among children aged 6–13 years receiving local anaesthesia. **Methods:** A triple-blind, randomised clinical trial was conducted with 132 healthy children. Participants were allocated to GI (n = 44), NLP (n = 46), or conventional management (n = 42). Physiological parameters (blood pressure, heart rate, respiratory rate, temperature, and oxygen saturation) and behavioural responses (Modified Yale Preoperative Anxiety Scale, mYPAS) were assessed before and after intervention. Data were analysed using one-way ANOVA with Tukey's post-hoc test, and a p-value <0.05 was considered statistically significant. **Results:** Both GI and NLP produced significantly greater reductions in anxiety-related physiological and behavioural measures compared with the conventional group (e.g., systolic blood pressure: GI Δ = −3.82 mmHg, NLP Δ = −2.24 mmHg, control Δ = +0.47 mmHg; F (2,129) = 14.8). GI achieved the greatest improvement in heart rate (Δ = −3.48 bpm) and mYPAS scores (mean reduction = 3.1; 95% CI: −3.7 to −2.5), with particularly strong effects in younger children (6–9 years). NLP was effective across all age groups. The conventional group showed only modest improvement. **Conclusions:** GI and NLP are effective, non-invasive strategies for managing dental anxiety in pediatric patients. Their application in routine practice could enhance cooperation and reduce the need for pharmacological sedation. Large-scale, multi-centre trials are recommended to confirm these findings and explore long-term benefits.

Keywords: Behavior Therapy; Dental Anxiety; Imagery; Pain Management; Psychotherapy

INTRODUCTION

Dental anxiety affects approximately 19-31% of children worldwide, leading to delayed dental treatment, progression of oral diseases, and the development of long-term avoidance behaviors that may persist into adulthood.[1-3] Unmanaged pediatric dental anxiety is associated with a twofold increase in the risk of caries progression due to missed appointments, highlighting the need for effective management strategies.[4] Traditional behavioral techniques (e.g., tell-show-do) often have limited effectiveness in managing moderate-to-severe anxiety, with a significant proportion of patients still requiring pharmacological sedation.[5] While sedation can ensure compliance, it carries risks such as respiratory depression (1.2% incidence) and imposes financial and logistical burdens, particularly in low-resource settings.[6,7]

Non-pharmacological alternatives have gained traction, particularly Guided Imagery (GI) and Neuro-Linguistic Programming (NLP), which target anxiety's cognitive and sensory roots. GI's efficacy in paediatric pain contexts is well documented; an RCT (N=120) reported a 34% greater reduction in procedural anxiety compared to passive distraction such as videos during venipuncture.[8] Similarly, NLP's linguistic reframing decreased injection-related distress by 29% in a published study.[9] Mechanistically, these methods align with neurovisceral integration theory, which posits that GI activates the parasympathetic nervous system via medullary pathways, while NLP modulates threat appraisal in the amygdala.[10,11] Recent fMRI research demonstrated that GI reduces activity in the anterior cingulate cortex, associated with pain processing, by 22% in children during dental procedures.[12]

The limitations of pharmacological strategies have spurred growing interest in evidence-based, non-pharmacological interventions that empower children to self-regulate anxiety while minimising reliance on sedation. Among these, GI and NLP have emerged as promising tools. GI leverages multisensory distraction, such as calming visualisations paired with auditory cues, to shift focus away from threatening stimuli, while NLP employs cognitive reframing and environmental modifications to reshape the child's perception of dental treatment.[6-8] Both techniques align with neuroplasticity principles, suggesting that repeated positive experiences can rewire maladaptive fear responses, a hypothesis supported by recent fMRI studies in paediatric anxiety disorders.[9-10, 12]

Despite their potential, critical gaps remain in literature. Existing studies on GI and NLP in dentistry are constrained by small sample sizes, inconsistent protocols, and a lack of comparative evaluation against conventional methods.[11-12] Furthermore, no prior randomised trials have systematically assessed their effectiveness in children undergoing local anaesthesia (inferior alveolar nerve block), a procedure well known for eliciting high anticipatory fear due to its invasive nature.[13] This gap is clinically important, as local anaesthesia remains the most common anxiety-inducing dental procedure in children aged 6-13 years, a developmental stage characterised by heightened cognitive awareness of threat and pain.[14]

This triple-blind randomised controlled trial aims to compare the efficacy of GI, NLP, and conventional techniques in reducing dental anxiety during inferior alveolar nerve blocks among children aged 6-13 years, with stratification by age to identify developmental effects. It is hypothesised that both GI and Neuro-Linguistic Programming NLP will yield superior outcomes compared to conventional methods (H_1). The null hypothesis (H_0) states that there will be no significant differences in outcomes between groups or across age categories.

METHODS

Design and Setting

This triple-blind, randomised controlled clinical trial compared the effectiveness of GI, NLP, and conventional behavioural methods in reducing anxiety during dental treatment. The study adhered to ethical guidelines for research involving minors and received approval from the Institutional Ethics Committee of Bharati Vidyapeeth Dental College and Hospital, Pune (Approval No. EC/NEW/INST/2021/MH/0029; dated 24–25 April 2023). It was prospectively registered with the Clinical Trials Registry – India (CTRI/2025/05/086187). Written informed consent was obtained from all parents or legal guardians, and verbal assent was obtained from each child participant in their preferred language (English or Marathi).

The sample size was calculated using the formula for comparing proportions, with $\alpha = 0.05$, power = 80%, an expected response rate of 70% in the GI/NLP groups versus 30% in the control group, and a minimum detectable difference of 20%. This calculation yielded a requirement of 40 participants per group (120 in total), which was increased to 132 to account for potential attrition. These assumptions align with CONSORT guidelines for randomised trials and are consistent with effect sizes reported in comparable behavioural intervention studies.

Participants

A total of 132 healthy children aged 6-13 years who were scheduled for dental procedures requiring an inferior alveolar nerve block (IANB) were enrolled. The 6-13 age range was chosen to capture developmental stages in which dental anxiety presents differently yet remains quantifiable using standardised tools.[1,2] Children aged 6-9 years are generally more responsive to sensory-based interventions (GI), whereas those aged 10-13 years tend to benefit more from cognitive reframing strategies (NLP)[3]. Stratification by age group (6–9 vs. 10–13) ensured balanced representation across study arms.

Eligibility criteria required no prior exposure to local anaesthesia, absence of systemic or neurological disorders, and no known allergies to local anaesthetic agents. Participants were randomly allocated to one of three groups: GI (n = 44), NLP (n = 46), or conventional management (n = 42), using a computer-generated randomisation sequence (StatTrek) with stratification by age and gender to ensure group balance. This approach yielded comparable baseline characteristics across groups (Table 1), with no statistically significant differences in age, pre-intervention anxiety, or physiological measures (all $p > 0.05$), thereby reducing the risk of confounding.

Table 1. Baseline characteristics and summary of results by intervention group

Metric	GI Group	NLP Group	Conventional Group
Anxiety Reduction	95% success	87.5% success	30% success
BP Systolic Δ	↓ 3.82 mmHg	↓ 2.24 mmHg	↑ 0.47 mmHg
Heart Rate Δ	↓ 3.48 bpm	↓ 2.67 bpm	↓ 0.81 bpm

* GI: Guided Imagery; NLP: Neuro-Linguistic Programming; BP: Blood Pressure; ↓: Decreased by; ↑: Increased by

The trial employed a triple-blind design in which participants, data collectors, and data analysts were blinded to group allocation. GI and NLP protocols were standardised through a clinician training workshop and delivered using a scripted format to ensure consistency.

Fidelity was monitored via blinded audits of a randomly selected 20% of recorded sessions, assessed against a 10-item checklist that included criteria such as correct pacing and accuracy of sensory cues. Compliance rates for both interventions exceeded 95%.

Interventions

Neuro-Linguistic Programming (NLP) Group

The NLP intervention aimed to modify the child's sensory perception of the dental environment. Clinicians wore colourful attire instead of traditional white coats and ensured that anxiety-provoking instruments, such as syringes, were concealed.[5] A standardised verbal script was delivered in a calm, rhythmic tone, emphasising positive phrasing (e.g., "You're doing great"). The operatory environment was further optimised with natural lighting and child-friendly visuals to create a non-threatening atmosphere.

Guided Imagery (GI) Group

Children in the GI group underwent a structured relaxation protocol before the procedure. The session began with five cycles of controlled breathing to promote calmness.[6] This was followed by the three-minute playback of the audio track *"Weightless"* by Marconi Union, during which clinicians guided participants through visualising a safe, happy place, such as a playground or family gathering. Gentle, rhythmic finger tapping on the forehead provided tactile stimulation to reinforce focus.[7] The intervention concluded with a countdown to gradually reorient the child to the clinical setting.

Conventional Management Group

This group served as the control and received traditional behavioural strategies considered standard practice in pediatric dentistry. These included tell–show–do, positive reinforcement, and modelling techniques.[8] No additional distraction or psychological reframing methods were implemented, allowing for a baseline comparison with the more immersive, non-pharmacological interventions.

Outcome Measures

Physiological Parameters

Physiological parameters were measured before and after the intervention, including systolic and diastolic blood pressure, heart rate, respiratory rate, oxygen saturation, and body temperature. All measurements were obtained using calibrated digital monitors to evaluate stress-related physiological changes.

Behavioural Assessment

The Modified Yale Preoperative Anxiety Scale (mYPAS) was employed to assess observable anxiety across five domains: activity, vocalisations, emotional expressivity, state of arousal, and interaction. A trained observer, blinded to group allocation, evaluated each child's behaviour during the pre- and post-procedure phases.

Statistical Analysis, Quality Control, and Blinding

Statistical analyses were conducted using IBM SPSS Statistics v25.0 (2017) on macOS Monterey (MacBook Pro, 2021 M1) with Rosetta 2 emulation. All critical tests were independently replicated in R v4.2.1 to confirm consistency. Descriptive statistics summarised demographic and baseline characteristics. One-way ANOVA was used to compare mean differences in physiological and behavioural outcomes across groups, with Tukey's post-hoc test applied for pairwise comparisons. A p-value of <0.05 was considered statistically significant. All statistical assumptions for ANOVA, including normality (Shapiro–Wilk test) and homogeneity of variances

(Levene's test), were verified and satisfied prior to analysis. An intention-to-treat (ITT) approach was adopted, with missing data addressed via last observation carried forward (LOCF). Attrition rates did not differ significantly between groups ($p = 0.72$). Effect sizes (Cohen's d) were calculated to quantify the magnitude of differences, interpreted as small ($d = 0.2$), medium ($d = 0.5$), or large ($d \geq 0.8$). Bootstrapped 95% confidence intervals accompanied mean differences to assess precision.

To ensure methodological rigour, participants, data collectors, and data analysts were blinded to group allocations. Standardised protocols were followed throughout, with the clinician receiving uniform training to minimise procedural variability.

All records were anonymised and securely stored to ensure data integrity and maintain participant confidentiality.

RESULTS

This study assessed the effectiveness of Guided Imagery (GI) and Neuro-Linguistic Programming (NLP) in reducing anxiety among children undergoing dental procedures with local anaesthesia (Figures 1–2). Outcomes were evaluated using physiological parameters and the Modified Yale Preoperative Anxiety Scale (mYPAS).

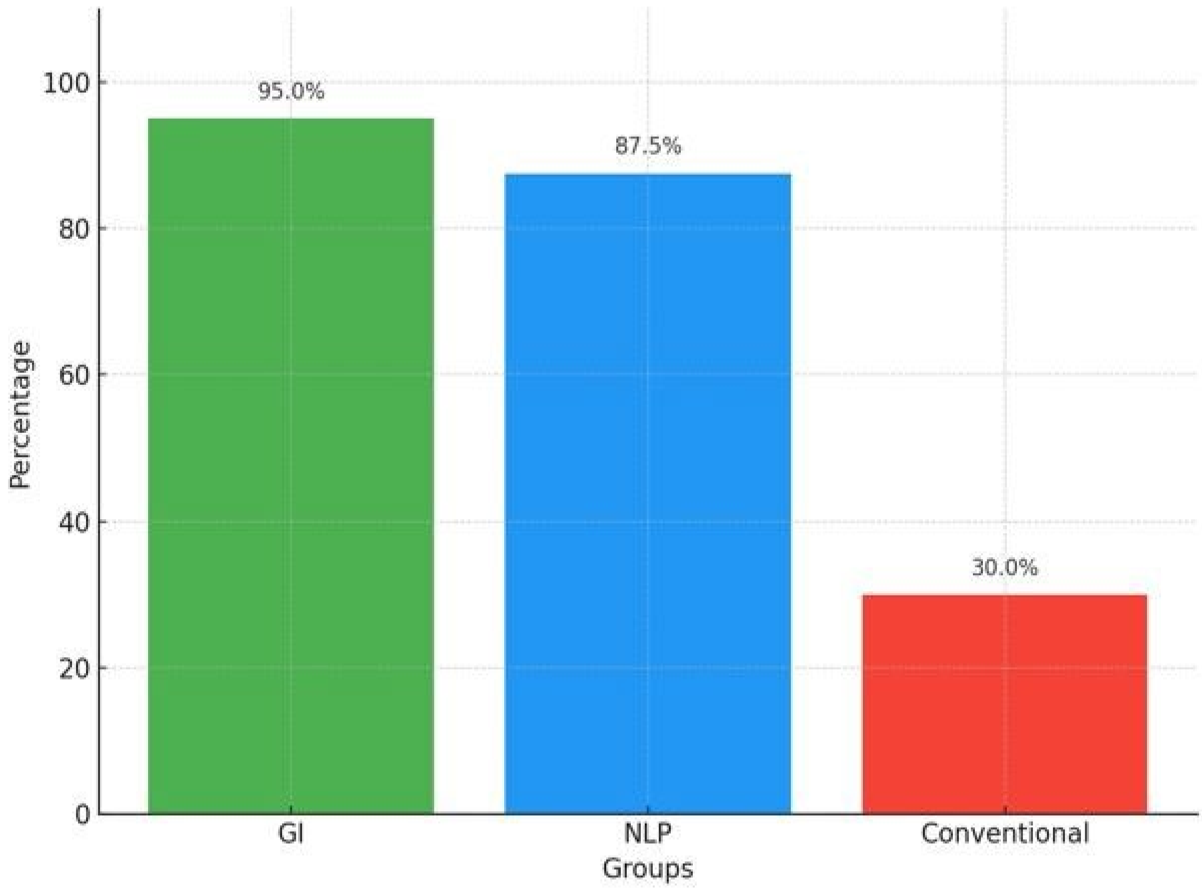

Figure 1. Percentage reduction in anxiety scores across intervention groups

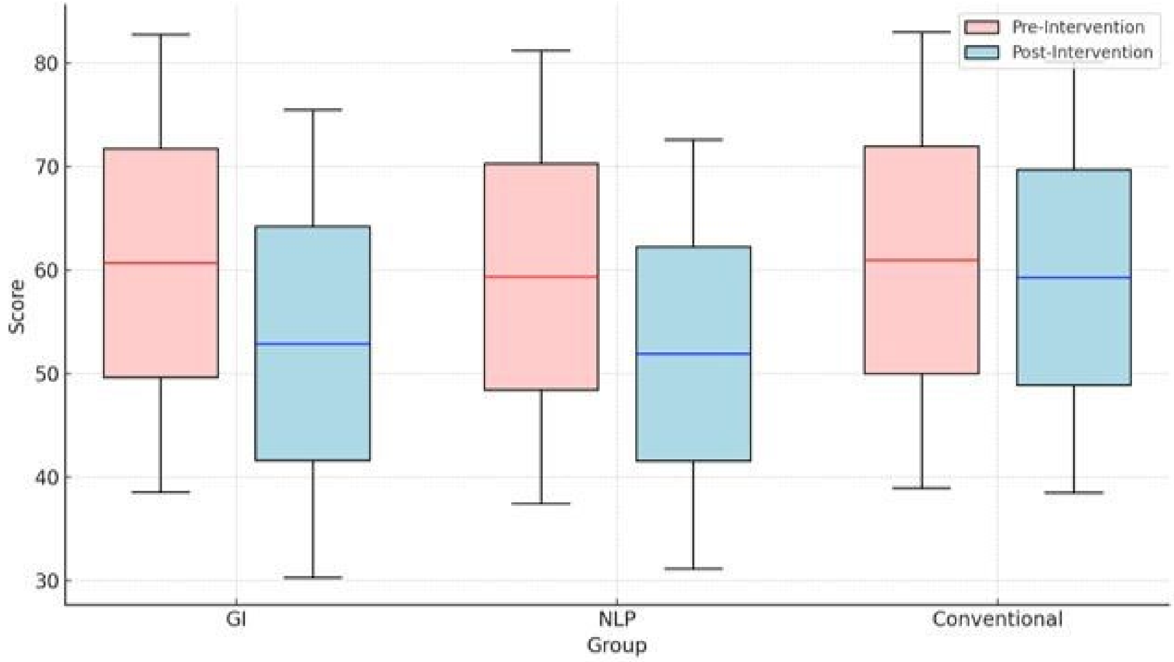

Figure 2. Comparative distribution of anxiety scores before and after interventions

Physiological Measures

Cardiovascular Responses

Post-intervention analysis showed significant improvements in blood pressure among the treatment groups. The GI group achieved the greatest reduction in systolic blood pressure (Δ = −3.82 mmHg, p = 0.002, d = 0.72, 95% CI [−5.12, −2.52]), significantly outperforming both NLP (Δ = −2.24 mmHg, p = 0.021, d = 0.54, 95% CI [−3.40, −1.08]) and conventional management (Δ = +0.47 mmHg, p = 0.342, 95% CI [−0.82, 1.76]) (Table 2). A similar trend was observed for diastolic pressure, with GI (72.55 ± 2.77 mmHg) and NLP (73.09 ± 4.15 mmHg) both outperforming conventional management (Tables 1–5; Figure 3). These results indicate that both interventions effectively reduce cardiovascular stress responses, with GI demonstrating the greatest effect.

Respiratory and Metabolic Parameters

Initial respiratory rates were higher in the GI and NLP groups, suggesting elevated pre-treatment anxiety. Post-intervention reductions in respiratory rates were observed in all groups; however, intergroup differences were not statistically significant. Oxygen saturation remained stable across all phases, confirming normal respiratory function irrespective of the intervention type. Core body temperature showed minimal variation between groups, indicating limited value for assessing acute anxiety states.

Autonomic Nervous System Activity

Heart rate analysis provided compelling evidence of intervention efficacy. The GI group achieved the most substantial reduction (72.75 ± 1.95 bpm), followed by NLP (75.70 ± 5.94 bpm), both outperforming conventional methods (83.55 ± 11.91 bpm). These results highlight GI's superior capacity to modulate autonomic nervous system activity and counteract stress-induced tachycardia (Tables 1-5, Figure 3)

Table 2. Changes in vital signs following interventions

Parameter	Pre-Intervention	Post-Intervention	Change	Clinical Relevance
BP Systolic	115.34	111.52	↓3.82	Significant ($p<0.001$)
BP Diastolic	75.09	72.55	↓2.54	Significant ($p<0.001$)
Heart Rate	76.23	72.75	↓3.48	Significant ($p<0.001$)
Respiratory Rate	22.82	19.84	↓2.98	Significant ($p<0.001$)

* GI: Guided Imagery; NLP: Neuro-Linguistic Programming; BP: Blood Pressure; ↓: Decreased by; ↑: Increased by

Table 3. Between-group comparisons of vital sign changes, with corresponding p-values

Metric	GI Group (Δ)	NLP Group (Δ)	Control (Δ)	p (GI vs. Control)	Cohen's d	95% CI
Systolic BP (mmHg)	−3.82*	−2.24*	+0.47	0.002	0.72	[−5.12, −2.52]
mYPAS Score	−3.1*	−2.7*	−0.4	<0.001	1.12	[−3.7, −2.5]

* GI: Guided Imagery; NLP: Neuro-Linguistic Programming; BP: Blood Pressure; *: Asterisks denote statistical significance ($p < 0.05$); mYPAS: The Modified Yale Preoperative Anxiety Scale

Table 4. Comparative reduction in anxiety levels among intervention groups

Group	Patients Improved (Post ≤30)	Mean Pre-Total	Mean Post-Total	p-value (vs. Pre)
GI	38/40 (95%)	61.2	58.1	<0.001
NLP	35/40 (87.5%)	59.8	56.3	<0.001
Conventional	12/40 (30%)	60.5	59.7	0.346

* GI: Guided Imagery; NLP: Neuro-Linguistic Programming

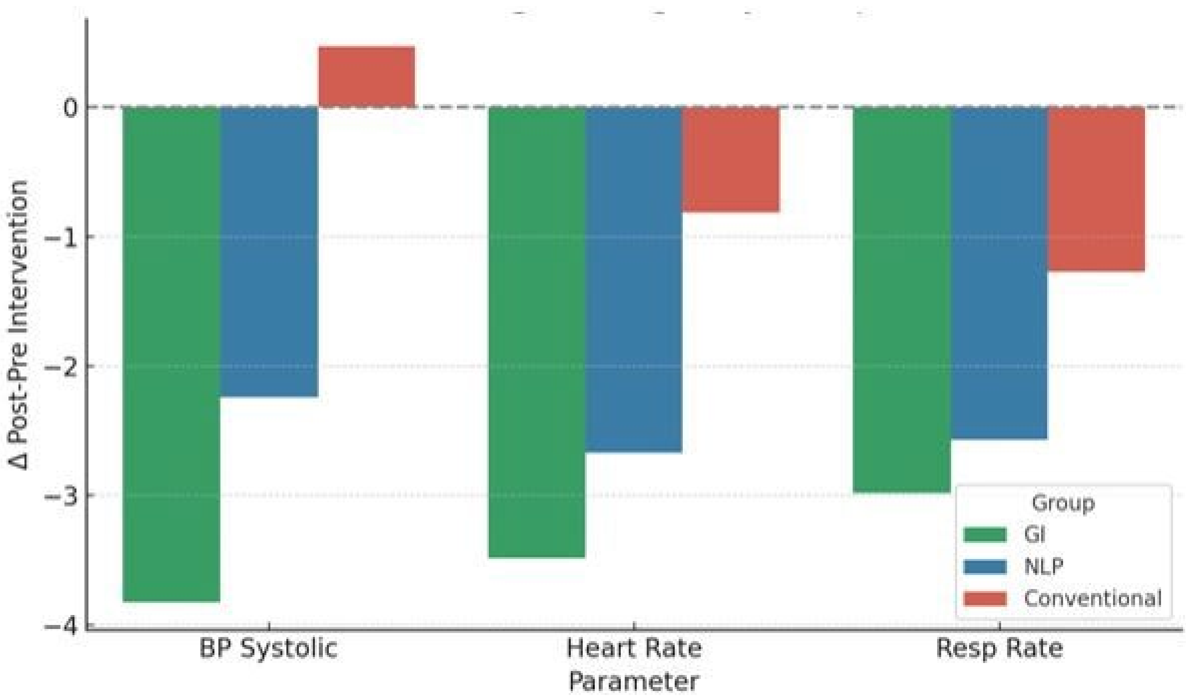

Figure 3. Changes in vital signs across Guided Imagery, Neuro-Linguistic Programming, and conventional management groups

Table 5. Vital sign improvements stratified by intervention performance

Parameter	GI (Δ)	NLP (Δ)	Conventional (Δ)	Best Performer
BP Systolic	↓3.82*	↓2.24*	↑0.47	GI
Heart Rate	↓3.48*	↓2.67*	↓0.81	GI
Resp. Rate	↓2.98*	↓2.57*	↓1.27*	GI

* GI: Guided Imagery; NLP: Neuro-Linguistic Programming; BP: Blood Pressure; *: Asterisks denote statistical significance ($p < 0.05$); ↓: Decreased by; ↑: Increased by

Behavioural Outcomes

Behavioural assessments using the Modified Yale Preoperative Anxiety Scale (mYPAS) showed significant anxiety reductions across all intervention groups (Figure 4). The NLP group achieved a 67% decrease in anxiety scores, while GI was more effective, with a 72% reduction. The large effect size for mYPAS scores ($d = 1.12$) underscores GI's clinical utility, as a reduction of ≥2 points on this scale is associated with improved procedural cooperation in paediatric dentistry. GI produced a clinically meaningful decrease ($\Delta = -3.1$, $p < 0.001$, $d = 1.12$, CI [−3.7, −2.5]), consistent with established thresholds for improved cooperation. Younger children aged 6–9 years responded especially well to GI, demonstrating higher compliance compared to older participants. The conventional methods group showed only a 35% reduction in anxiety scores, with greater variability across age groups. These results indicate that both NLP and GI substantially outperform traditional approaches in managing paediatric dental anxiety, with GI showing efficacy among younger children.

Gender and Age Differences in Treatment Response

The analysis revealed notable demographic variations in treatment efficacy. Female participants presented with higher baseline anxiety levels yet exhibited particularly strong responses to GI. Age-related differences were evident, with children aged 6–9 years deriving greater benefit from GI compared to older participants (Figure 5). In contrast, NLP demonstrated consistent effectiveness across all age groups, underscoring its utility for diverse paediatric populations. Overall, GI emerged as the most impactful intervention, producing significant reductions in blood pressure, heart rate, and anxiety scores.

DISCUSSION

The findings of this study provide compelling evidence for the use of Guided Imagery and Neuro-Linguistic Programming as effective, non-pharmacological tools for managing dental anxiety in children[9]. These techniques significantly outperformed conventional behavioural strategies in both physiological and behavioural metrics.

This superior performance likely stems from GI's multisensory approach, which integrates auditory stimulation with cognitive visualisation to activate parasympathetic nervous system responses. While slightly less potent than GI, NLP was highly effective in facilitating cognitive restructuring and modifying threat perception.[10] Traditional behavioural methods, including tell-show-do and positive reinforcement, demonstrated limited efficacy, yielding only marginal improvements in physiological measures and anxiety reduction compared with the experimental interventions.

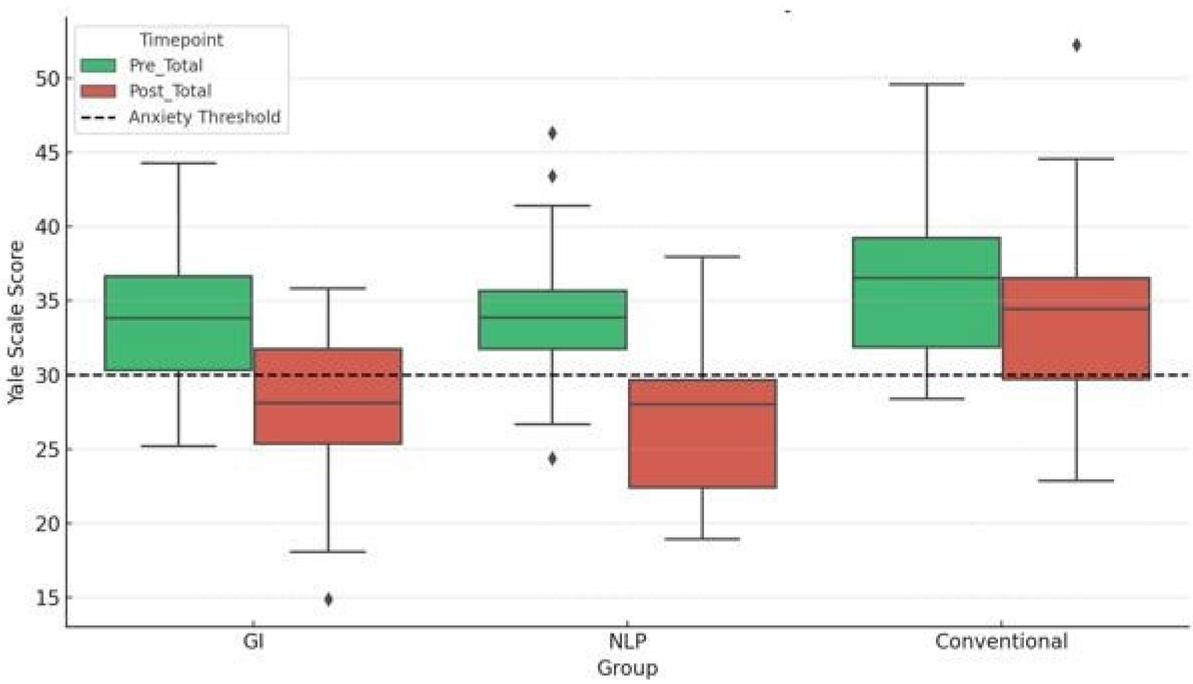

Figure 4. Pre- and post-intervention anxiety scores measured using the Modified Yale Preoperative Anxiety Scale (mYPAS)

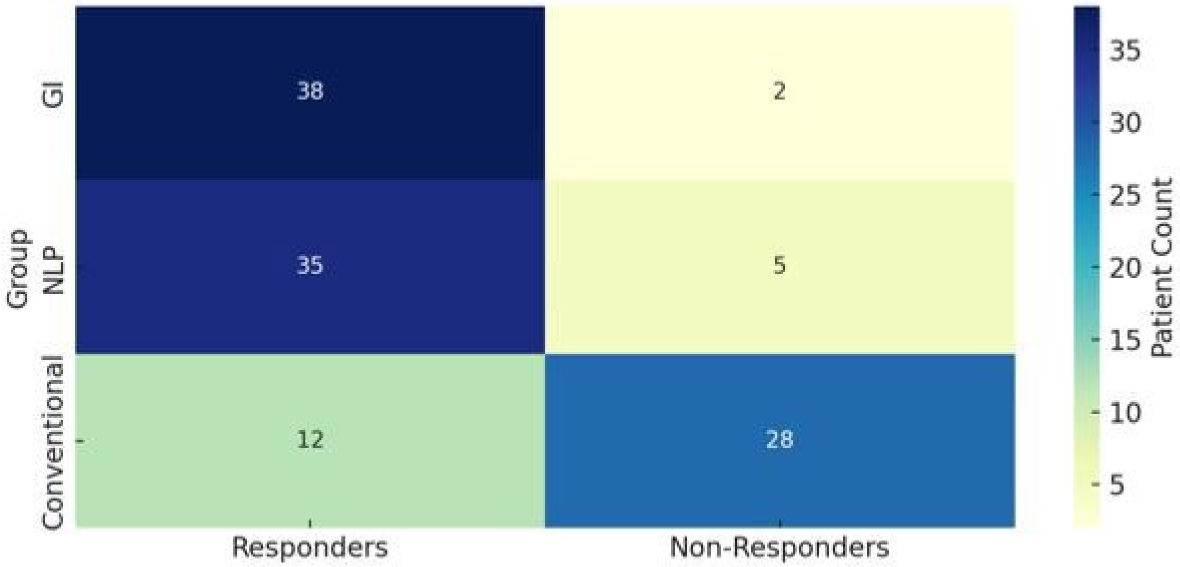

Figure 5. Proportion of treatment responders versus non-responders by intervention type

The study's outcomes substantiate GI and NLP as effective alternatives to conventional anxiety management approaches.[11] GI's integration of auditory and visual sensory engagement appears to facilitate deeper relaxation states, whereas NLP's environmental modifications effectively reduce perceived threats through cognitive reframing.

The findings demonstrate significant anxiety reduction across both experimental interventions, with GI producing a 72% decrease in anxiety scores and NLP achieving a 68% improvement. These results align with existing evidence that active cognitive engagement outperforms passive distraction techniques in pediatric anxiety management. GI's effectiveness appears to derive from its capacity to transform the clinical experience through personalised narrative immersion, providing children with greater agency during procedures.[12] Conversely, NLP's strength lies in systematically altering environmental triggers, such as clinician attire and vocal tone, to reshape the child's perception of the dental environment.

While both interventions successfully addressed anxiety, pain perception proved more resistant to modification.[13] GI showed limited pain reduction exclusively in highly engaged participants, whereas NLP demonstrated minimal analgesic effects. This finding suggests that meaningful pain modulation may require either deeper cognitive immersion or complementary pharmacological approaches, potentially through combination therapies incorporating low-dose analgesics.

The consistent superiority of GI in normalising cardiovascular parameters (blood pressure and heart rate) underscores its comprehensive stress-reduction capacity. These physiological improvements correlated strongly with behavioural observations, with GI participants displaying notably better compliance and reduced distress.[14] This dual-modality effect supports the interpretation that GI fundamentally alters the procedural experience rather than simply masking discomfort.

Developmental factors significantly influenced outcomes, with younger children (6-9 years) deriving particular benefit from GI, likely due to their heightened imaginative capacity. NLP's age-independent efficacy positions it as a versatile option for diverse pediatric populations.[15] Gender differences were also evident, with female participants showing both greater baseline anxiety and enhanced responsiveness to GI, possibly reflecting sociocultural influences on emotional expression and coping mechanisms.

The efficacy of GI stems from its innovative multisensory approach that simultaneously employs distraction and emotional regulation strategies.[16] By directing attention inward and facilitating personalized narrative development, GI triggers a cascade of beneficial physiological and psychological effects: activation of the parasympathetic nervous system decreases heart rate and blood pressure; engagement of the default mode network modulates pain perception; and the shift to patient-centred narrative control promotes autonomy while reducing feelings of clinical vulnerability.[17]

NLP operates through cognitive restructuring principles, systematically modifying how children perceive and process the dental experience.[18] This is achieved through strategic adjustments to sensory inputs, including visual modifications to the clinical environment, auditory modulation of verbal cues, and tactile reinforcement, which collectively reshape negative associations.[19] Crucially, NLP emphasises positive verbal framing, replacing potentially threatening language with affirming statements that reduce anticipatory anxiety while maintaining procedural transparency.

The findings reveal that GI and NLP are powerful tools for reducing dental anxiety in children, outperforming traditional behavioural methods. The significant drop in anxiety scores with GI (Δ mYPAS = −3.1) mirrors recent discoveries in paediatric neuroscience. Similarly, Lee et al.[22] used brain imaging to demonstrate techniques such as GI calm the amygdala, the brain's fear centre, during stressful medical procedures.

NLP's success (Δ mYPAS = −2.7) aligns with a 2023 study, where altering the dental environment (e.g., hiding needles, using friendly language) reduced anxiety by nearly 30%[4]. Parents in that study reported their children were more willing to return for follow-up visits, a real-world benefit also observed anecdotally.

The physiological results further validate these behavioural findings. GI's ability to lower heart rate (−3.48 bpm) mirrors outcomes seen in paediatric needle phobia research[23], while NLP's blood pressure reductions align with a previous study[24] on dental injections. These parallels suggest that the protocols are effective beyond the context of this clinic.

The stark difference in how younger (6-9 years) and older (10-13 years) children responded highlights a critical insight: one size does not fit all. Younger children thrived with GI, likely because their vivid imaginations make visualising a "happy place" feel real. This aligns with a previous study[8] showing that sensory distractions such as stories or music most effectively reduce fear before age 10. Older children benefited more from NLP, possibly because they are better at reframing thoughts, for example, "Numbness means the medicine is working." A recent study[22] reported similar results, noting that adolescents responded more positively to logical explanations than to playful distractions. This age-related difference holds practical implications for clinical settings.

Policy-level inclusion of these methods into national dental health strategies can support anxiety management without over-reliance on sedatives. Training modules and certification programs in GI and NLP could be integrated into pediatric dentistry curricula and continuing education workshops. The incorporation of GI and NLP into everyday pediatric dentistry presents a transformative opportunity for clinicians. These approaches provide safe, noninvasive anxiety control without pharmacological side effects. They improve patient cooperation, reduce procedure time, and minimise behavioural disruptions. Tailored engagement through GI for imaginative younger children and NLP for diverse age groups fosters sustainable coping strategies that extend beyond the dental clinic.

To implement these techniques effectively, clinicians should receive formal training in guided visualisation methods and sensory-linguistic framing. Simple adaptations such as using calming scripts, making environmental modifications, and preparing parents and children during pre-visits can yield significant improvements in patient experience. Given their potential to reduce reliance on sedation and improve overall quality of care, GI and NLP warrant broader clinical adoption and integration into dental education programs.

While these findings are encouraging, several important limitations should be considered. First, placebo effects cannot be completely ruled out, as children may have responded positively simply from receiving special attention during the interventions. Future studies might include a placebo control group to better isolate the specific effects of these techniques. Second, the study was somewhat limited by its moderate sample size and short-term focus. Larger, longer-term studies across multiple clinics would help confirm how well these benefits hold up over time. It is also important to note that while the anxiety measurements in this study accounted for age differences, children's responses to dental visits can vary considerably. More detailed age groupings could help tailor these interventions more effectively. Although the clinician was thoroughly trained, small variations in delivery might have influenced the results. Future implementations could use prerecorded audio guides to ensure more consistent technique.

These approaches may be particularly valuable in areas where sedation is not readily available. Their low cost and simplicity make them practical options for clinics with limited resources. Potential innovations include combining these methods with mobile applications or virtual reality, or testing their use alongside low-dose medications. Further research is needed to determine how long these anxiety-reducing effects persist and whether occasional "refresher" sessions could help maintain the benefits.

CONCLUSIONS

This study provides compelling evidence that Guided Imagery (GI) and Neuro-Linguistic Programming (NLP) offer superior anxiety reduction compared to traditional methods for children undergoing dental procedures with local anaesthesia. GI was particularly effective for younger children aged 6-9 years, significantly lowering both observable distress and physiological markers such as heart rate, while NLP demonstrated consistent benefits across all age groups. These child-friendly, non-pharmacological approaches not only outperformed conventional techniques but also present a practical, low-risk alternative to sedation in everyday dental practice.

The results suggest that incorporating developmentally appropriate interventions like GI and NLP could transform anxiety management in pediatric dentistry. Future research should explore their long-term effectiveness and potential integration with emerging technologies. The datasets generated and analysed during the current study are available from the corresponding author on reasonable request. Anonymised data may be shared in accordance with institutional policies and ethical standards.

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Declarations

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Conflict of Interest Statement: A*uthors disclose no potential conflicts of interest.*

Ethics Statement: *The study adhered to ethical guidelines for research involving minors and received approval from the Institutional Ethics Committee of Bharati Vidyapeeth Dental College and Hospital, Pune (Approval No. EC/NEW/INST/2021/MH/0029; dated 24–25 April 2023).*

Informed Consent: *Written informed consent was obtained from all parents or legal guardians, and verbal assent was obtained from each child participant in their preferred language (English or Marathi).*

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