Original Article

Comparative evaluation of anxiety level during restorative treatment using no music, monaural beats, and binaural auditory beats as audio distraction behavior guidance technique in children aged 6–12 years: A randomized clinical trial

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ABSTRACT

Background: Binaural auditory beat is an auditory illusion perceived when two different pure-tone sine waves with less than a 30 Hz difference are presented to a listener dichotically. Monaural beat stimulation is achieved by the superposition of amplitude-modulated signals of nearby frequencies to both ears simultaneously. **Aim:** The study aims to evaluate and compare anxiety level during restorative treatment using no music, monaural beats, and binaural auditory beats as audio distraction behavior guidance techniques in children aged 6–12 years. **Settings and Design:** Three-arm, parallel-group randomized study was conducted in the department of pediatric and preventive dentistry. **Materials and Methods:** The sample size of 45 participants was calculated and allocated into three groups as no music, monaural beats, and binaural auditory beats group. Teeth with Class I cavity in primary or permanent molars were prepared and restored. Anxiety was measured pre and postintervention using pulse oximeter and Venham's picture test. **Statistical Analysis Used:** Data obtained were analyzed with SPSS software version 20.0 and were carried out using one-way analysis of variance and dependent *t*-test and significance value < 0.05 was considered. **Results:** Binaural auditory beats and monaural beats showed a better reduction in anxiety levels as per Venham's picture test scores with statistically significant "*P*" value 0.0001 and 0.064, respectively. Likewise, binaural auditory beats showed better reduction in anxiety levels as per pulse rate scores with statistically significant "*P*" value 0.0001 as compared to conventional treatment technique. **Conclusion:** Binaural auditory beat was found to be the most effective followed by the monaural beat compared to the control group. Thus, binaural auditory beats and monaural beats

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can be used effectively as an essential aid to reduce anxiety in children.

KEYWORDS: Anxiety, audio analgesia, behavior guidance technique, binaural auditory beats, children, monaural beats

Introduction

Dental anxiety refers to a state of apprehension that something dreadful might happen during dental treatment. Among various anxieties, it is placed at the fourth position.[1]

The prevalence of dental fear and anxiety has been reported to be around 5%–30% among different countries.[2] Children with dental fear and anxiety often avoid or delay dental treatment, causing longer appointment durations and unpleasant experiences for both the child and the dentist. This behavior increases the likelihood of missed appointments, leading to neglected dental care and the need for more complex and costly treatments such as conscious sedation or general anesthesia. Consequently, dental fear and anxiety have a detrimental effect on the quality of dental treatment. To address this issue, pediatric dentists should employ newer behavior guidance techniques to efficiently and effectively manage children, ensuring positive psychological impacts on oral health and dentistry.[2]

Behavior guidance techniques are crucial for alleviating anxiety, fostering a positive dental attitude, and ensuring safe and efficient oral health care.[2] Among these techniques, nonpharmacological methods effectively address disruptive behavior by replacing negative behavior with cooperative behavior. Distraction, specifically audio distraction, is a commonly employed technique in dental clinics, as it is nonaversive and easily accepted by children. Music during stressful dental procedures effectively distracts children, enabling them to manage their behavior.[3]

According to McCaul and Mallot's theory, distraction from an unpleasant stimulus reduces an individual's perception of pain. The duration of concentration on the painful stimulus directly influences pain perception.[4] Robert and Sowray's cross-sensory mechanism explains the suppression of the pain pathway, highlighting the close association between pain and auditory pathways in the reticular formation and lower thalamus. These interactions are highly inhibitory, leading to the stimulation of an inhibitory sensory pathway and the masking of pain impulses through auditory stimulation. Consequently, dental anxiety is reduced.[5]

Audio analgesia, originally proposed by Gardner and Licklider in 1959, refers to the application of sound-based techniques to alleviate pain during various medical procedures, including dental treatments.[6] The iso principle in music involves matching the initial emotional state with the desired state through carefully selected and sequenced music, amplifying its mood-regulating effects. This approach acknowledges music's potential to influence emotions and promotes emotional regulation by gradually transitioning the individual's mood.[7] By aligning musical pieces with the individual's emotional journey, the iso principle enhances the effectiveness of mood regulation through music. One specific application of the iso principle is the use of binaural beats.

Binaural auditory beats were first described by Dove in 1939. Later, it was described in detail by Oster in 1973. It is an auditory illusion perceived when two different pure-tone sine waves are presented one to each ear at a steady intensity and frequency. When a relaxed state is desired, a binaural tone with a frequency that matches the alpha brainwaves (8–12 Hz) can serve the purpose.[8] The binaural beats are able to alter the functional connectivity at the auditory cortex and have been reported to have significant brainwave entrainment effects. This brainwave entrainment achieved due to alpha wave stimulation could possibly lead to the release of the hormone endorphin which would result in the clinical effect of relaxation of the children.[9]

Monaural beat stimulation is achieved by administrating the same amplitude-modulated signal to both ears simultaneously. As both ears receive the same beat wave, perception of the beat does not require an integration of information from the two ears.[10]

Due to limited research comparing anxiety levels using monaural beats and binaural auditory beats as audio distraction techniques in children, this study aimed to validate and enhance the understanding of the clinical effectiveness of binaural beats in reducing anxiety during pediatric dental procedures.

Materials and Methods

This study was a three-arm, parallel-group randomized study conducted in the department of pediatric and preventive dentistry. Ethical approval was obtained from the research and ethics committee and permission to conduct the study was obtained from the institutional review board. The sample size of 45 was calculated by standard sample size calculating formula $n = \frac{2S^2 (Z_{1-\alpha} + Z_{1-\beta})^2}{d^2}$, ($Z_{1-\alpha}$ = *Z*-value for α level [2.58 at 1% α error or 99% confidence] and $Z_{1-\beta}$ = *Z*-value for β level [0.842 at 20% β error or 80% power]).[11]

The children were selected using the following selection criteria: children between 6 and 12 years of age visiting

Figure 1: Evaluation of preoperative anxiety using Venham's picture scale

Figure 3: Patient undergoing dental treatment

dental clinic for the first time who require restoration for Class 1 cavity in the primary/permanent molar teeth with moderate dental caries involving enamel and dentin were included in the study. Whereas children with special health-care needs, those showing Frankl behavior ratings 1 and 2 (i.e. definitely negative and negative). Children having visual or auditory impairment and children and/or parents who are unwilling to participate in the study were excluded from our study.

All the 45 children were allocated randomly into 3 equal groups of 15 each by simple random sampling using lottery method to ensure standardization. Children allocated to Group I was treated without any music intervention, Group II using monaural beats, and Group III was treated using binaural auditory beats. The principal investigator was blinded as the participants in Group II and Group III were presented with beats by means of over-the-ear headphones by a trained assistant. The participants in Group I were

Figure 2: Evaluation of preoperative anxiety using pulse oximeter

not introduced to any music intervention; however, over-the-ear headphones were presented to them as well for blinding of principal investigator.

Children who fulfilled inclusion and exclusion criteria were made to sit comfortably on the dental chair, and the procedure was completely explained to the parents as well as the children by the principal investigator. After recording the preliminary information, a clinical examination was carried out on a dental chair under standard operating protocol. Behavior of the children before the study was evaluated according to Frankl Behavior Rating Scale for selection of the participant in the study.[12]

The anxiety of the participants was evaluated by a trained pediatric dentist using Venham's picture test before the commencement of restorative procedure.[13] The Venham's picture test comprises eight cards, with two figures on each card, one "anxious" figure, and one "nonanxious" figure. The children were asked to point at the figure they felt most like at that moment [Figure 1]. All cards were shown in their numbered order. If the child pointed at the "anxious" figure, a score of one was recorded, and if the child pointed at the "nonanxious" figure, a score of zero was recorded. The number of times the "anxious" figure was chosen and was totaled to give a final score (minimum score: 0; maximum score: 8). Similarly, the physiological parameter such as pulse rate of the participants was recorded using a fingertip pulse oximeter device with an integrated monitor displaying values of pulse rate to evaluate the anxiety subjectively by a pediatric dentist [Figure 2].[14] Informed consent was obtained from all the parents/guardians of children participating in the study.

The children in the binaural auditory beat group were presented with beats of frequencies 400 Hz and 412 Hz in the left and right ears, respectively, superimposed on soft, relaxing music (to utilize their synergistic effect) by means of over-the-ear headphones using the mobile

device. The frequencies were produced by software (Brain Waves Binaural Beats, MynioTech Apps, Chapeco, Santa Catarina, Brazil) as used in the previous studies and the treatment procedure was started thereafter.[8,15] The monaural beat used for the current study was generated using the Windows Media Player application and was created using Tone Generator (NCH software, Canberra, Australia) by applying beats at frequency of 10 (alpha wave) where two sine waves were superposed and resulted in a monaural beat with a carrier frequency of 220 Hz and a modulation frequency which of 10 Hz. A sound pressure level of 60 dB was used for the study.

The Principal Investigator performed the restorative procedure under Standard Operating Protocols [Figure 3]. The procedure was carried out in 45 min for each child in all the three groups. The teeth selected for the study were isolated using rubber dam and the tooth preparation for Class I cavity was carried out in primary or permanent molars. Teeth were restored using posterior high-strength glass ionomer for primary molars and composite resin for permanent molars.

At the end of the restorative procedure, anxiety was again assessed using Venham's picture test and pulse oximeter and the postoperative recordings were noted for further analysis.

The data were obtained from physiological measure and psychometric scale was analyzed statistically with the Statistical Package for the Social Sciences (SPSS) software version 20.0 (SPSS Inc., Chicago, IL, USA). Metric continuous data were presented as mean ± standard deviation. The analysis between groups was carried out using one-way analysis of variance (ANOVA). If the *P* value in one-way ANOVA was < 0.05, a "Tukey's multiple *post hoc* analysis" was performed to detect differences between two groups. Categorical data were presented as actual numbers and percentages. Categorical variables were analyzed with "dependent *t*-test." For statistical significance, the probability value of < 0.05 was considered.

Results

Demographic profile of the participants is depicted in Table 1. Forty-five children with mean age of 8.96 ± 2.26 were included in this study. 28 out of 45 were male and 17 of the participants were female. All the groups showed equitable distribution of participants which maintained standardization of selection criteria in our study.

When comparison of baseline and postoperative Venham's picture test scores was carried out in three groups using dependent *t*-test and one-way repeated measures of ANOVA, a very highly statistically significant difference was found in binaural auditory beats group with a "*P*" value of 0.0001 ($P < 0.05$) indicating it to be the most efficient in reduction of anxiety. This was closely followed by monaural beats group with a "*P*" value of 0.0064 ($P < 0.05$) which also showed a statistically significant difference between baseline and postoperative Venham's picture test. On the contrary, no significant difference was observed in control group [Graph 1].

When pairwise comparison was done between control group and monaural beats group, a statistically significant difference was observed as indicated by a "*P*" value of 0.042 ($P < 0.05$). The difference between control group and binaural auditory beats groups also had a very high statistically significant "*P*" value of 0.0013 ($P < 0.05$). However, on comparing monaural beats group with binaural auditory beats group, a nonstatistically significant difference was observed which indicated the efficacy of both the modalities in reducing the anxiety among children during restorative treatment [Table 2].

When a comparison of baseline and postoperative pulse rate was done among three groups using one-way ANOVA, maximum decrease was observed in binaural auditory beats group as the difference between the baseline and postoperative scores was the highest with a "*P*" value of 0.0001. Monaural beats group showed a slight decrease in pulse rate but the difference was statistically nonsignificant [Graph 2].

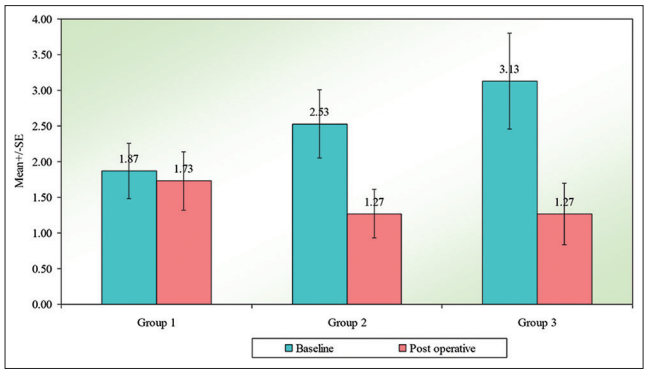
Discussion

Music aids relaxation as it diminishes the noise of the dental drill and diverts attention from actual dental

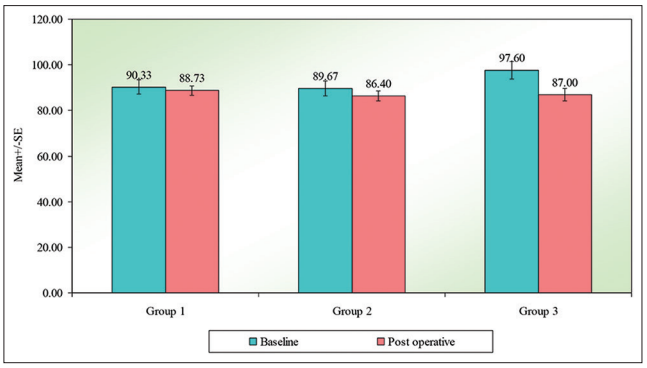
Table 1: Demographic profile of children in three groups (1, 2, 3)

	Group 1	Percentage	Group 2	Percentage	Group 3	Percentage	Total	Percentage	χ^2	*P*
Age groups (years)										
<10	9	60.00	5	33.33	9	60.00	23	51.11	3.4820	0.1750
≥10	6	40.00	10	66.67	6	40.00	22	48.89		
Age, mean±SD	8.60±2.59		9.47±2.13		8.80±2.08		8.96±2.26			
Gender										
Male	11	73.33	11	73.33	6	40.00	28	62.22	7.1770	0.0280*
Female	4	26.67	4	26.67	9	60.00	17	37.78		
Total	15	100.00	15	100.00	15	100.00	45	100.00		

*$P<0.05$. SD=Standard deviation



Graph 1: Comparison of baseline and postoperative Venham's picture test scores in three groups (1, 2, 3)



Graph 2: Comparison of baseline and postoperative pulse rate scores in three groups (1, 2, 3)

Table 2: Pair-wise comparison of three groups (1, 2, 3) with baseline and postoperative Venham's picture test scores by Tukey's multiple *post hoc* procedures

Times	Groups	Group 1	Group 2	Group 3
Baseline	Mean±SD	1.87±1.51	2.53±1.85	3.13±2.59
	Group 1	-		
	Group 2 (*P*)	0.6440	-	
	Group 3 (*P*)	0.2141	0.6996	-
Postoperative	Mean±SD	1.73±1.58	1.27±1.33	1.27±1.67
	Group 1	-		
	Group 2 (*P*)	0.6848	-	
	Group 3 (*P*)	0.6848	1.0000	-
Difference	Mean±SD	0.13±0.64	1.27±1.53	1.87±1.36
	Group 1	-		
	Group 2 (*P*)	0.0420*	-	
	Group 3 (*P*)	0.0013*	0.3885	-

*P<0.05. SD=Standard deviation

treatment. This also minimizes the awareness of dental treatment. Distraction draws the attention of child away from unpleasant stimuli to accomplish dental treatment with desired quality.

It has proven useful for its relaxing effects and easing anxiety by affecting the limbic system of the brain and providing release of endorphin and enkephalin, which causes reduction in dental anxiety. Music also activates parasympathetic nervous system and causes a decrease in physiological findings such as blood pressure, pulse and respiration, and reducing dental anxiety.[5]

Recent studies on nonpharmacological methods of reducing anxiety such as animal-assisted therapy, aroma therapy, Snoezelen sensory-adapted dental environment, virtual reality, and guided imagery have shown to reduce the anxiety levels. Most of these methods require a separate area or special equipment to achieve successful results, which could increase the cost for the dentist. However, with auditory beat stimulation, dentist can treat the child on the same dental chair with minimal outlay, making it an economical alternative. Hence, the present study was undertaken to evaluate the anxiety levels during restorative treatment using no music, monaural beats, and binaural auditory beats as audio distraction behavior guidance techniques in children aged 6–12 years.

Our study included children aged between 6 and 12 years as children in this age group are competent to understand the concepts of pain and anxiety making the self-reporting scales more reliable. In our study, Venham's picture test was used to subjectively assess the anxiety in children as it is projective, psychometric, and self-measure test that has shown to be a valid means of assessing child dental anxiety in a clinical context.[13,16] Whereas for the objective assessment of anxiety, pulse oximeter was used as increase in heart rate due to anxiety is a direct result of sympathetic stimulation. Thus, using both psychometric and physiological methods of assessment can play an important role to provide qualitative and quantitative estimation of anxiety.

Binaural auditory beats have been used to alleviate anxiety in numerous studies.[8,15,17] No previous study has evaluated and compared binaural auditory beats and monaural beats among children during dental treatment. In the present study, the participants in the binaural auditory beats experienced reduced anxiety and the difference was statistically significant compared to the control group scores. These results are in accordance with the studies done by Isik *et al*., Singh *et al*., Chairinkam *et al*., Menziletoglu *et al*., and Padmanabhan *et al*.[8,11,17-19] The probable reason for the successful reduction of anxiety using binaural auditory beats could be that it activates the functional connectivity at auditory cortex that leads to brainwave entrainment effect which in turn releases the hormone endorphin. It also suppresses the pain-evoked neural activity by auditory stimuli in the posterior group nuclei of the thalamus and in the cerebral cortex as reported by Mountcastle which would result in the clinical effect of relaxation of the child.[20]

Brainwave entrainment utilizes diverse brainwave frequencies such as alpha, beta, gamma, delta, epsilon, and theta to influence cognitive and behavioral

responses. By manipulating these frequencies, brainwave entrainment achieves synchronization within the brain, promoting balanced neural activity.

This technique offers a range of benefits. For example, alpha waves (8.0–11.9 Hz) induce relaxation and tranquillity, while beta waves (12.0–29.9 Hz) enhance focus and concentration. Gamma waves (30–100 Hz) support cognitive processing, memory, and creativity, and delta waves (0.5–3.9 Hz) are associated with deep sleep and restoration. Epsilon and theta waves (4.0–7.9 Hz) are linked to deep meditation, intuition, and profound relaxation. By harnessing brainwave entrainment, individuals can tap into these specific states for personal growth, stress reduction, improved sleep, and overall well-being.

When an individual listens to such binaural auditory beat, his brain will attempt to adjust its own brainwave to the frequency of the external stimuli (alpha brainwave) that aid in relaxation. Literature suggests that tones with a frequency from 200 to 900 Hz are more effective in provoking binaural auditory beat than those which exceed 1000 Hz.[19,21] The difference in frequency between the two sounds must be less than 30 Hz for the beats to occur, otherwise, the two tones are captured independently and no beats are perceived.[8] A sound pressure level of 60 dB was used for the study as the previous study conducted showed that auditory beat stimulation at 60 dB is sufficient to induce pronounced electrophysiological effects.[22]

In the present study, we used binaural auditory beats with a superimposed musical composition as the data showed that there was no significant difference between original binaural auditory beats and superimposed binaural auditory beats.[23] We chose beat stimulus of 12 Hz for binaural auditory beat and 10 Hz for monaural beats as previous studies have reported decreases in anxiety using similar frequencies.

Despite the prevalence of studies utilizing binaural beats as stimuli, evidence suggests that cortical responses to monaural beats are stronger.[24,25] In light of this, our research aimed to explore whether monaural beats have a similar impact on binaural beat stimulation. A previous study on monaural beat stimulation demonstrated a reduction in state anxiety and cognition.[10] In our current investigation, the use of monaural beats resulted in a statistically significant decrease in anxiety levels. The exact mechanism behind this effect remains unclear, but it is hypothesized that the modulation of the physical beat signal in the cochlea and subsequent transmission through brain stem neurons to the auditory cortex may enhance alpha phase synchronization, leading to anxiety reduction.

Binaural beats are subjectively perceived as being inside the head and are modulated at the brainstem level in the superior olivary nuclei, while monaural stimuli are modulated at the cochlear level.[25]

Our study underscores the effectiveness of binaural and monaural beats in reducing anxiety during pediatric dental treatment. The results demonstrate their superiority to conventional techniques, as evidenced by highly significant differences in anxiety scores. In addition, this approach offers an economical alternative to other modalities. Future research could benefit from a larger sample size and broader age group to enhance generalizability to the population as a whole.

Owing to their entrainment effects on the brain to release endorphin, they may aptly be termed as digital drugs that could prove as a melody turning out to be remedy which can be used as an essential aid in reducing the anxiety in children.

Limitations of the study were like every other technique, this too had its drawbacks, none of which are insurmountable. The child has no control over the choice of music to be played. Furthermore, music may tend to hinder the communication between dentist and child.

Clinical significance pertaining to dentistry is the findings that we achieve from this study which is helpful in estimating the effectiveness of a nonpharmacological behavior management adjunct that will aid dentists in gaining cooperation and managing the children effectively in dental operatory.

The futuristic idea of our study is to combine binaural auditory beats and monaural beats with visual relaxing stimuli which could have an even greater scope in reducing child's apprehensiveness more effectively. Thus, there is a good ambit to conduct more research in this regard with a larger sample size.

Conclusion

Thus, the present study illustrates that binaural auditory beat was found to be most effective followed by monaural beat compared to control group. Both are novel methods that can efficiently serve as a safer and effective adjunct for the behavior management of children.

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Conflicts of interest
There are no conflicts of interest.

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