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ORIGINAL ARTICLE

# Robotic approach to the reduction of dental anxiety in children

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**ABSTRACT**

**Objective:** We introduced a humanoid robot for the use of techno-psychological distraction techniques in children aged 4–10 to reduce their anxiety and improve their behaviour during dental treatment.

**Materials and methods:** Two hundred children (98 boys, 102 girls; mean age: $6.5 \pm 1.66$ years) appointed for first time for dental caries were included and randomly divided into two groups [$N = 100$ for each group; RG: Robot Group (accompanied by the robot), CG: Control Group (without robot accompaniment)]. Half of the children were treated under local anaesthesia (infiltration anaesthesia) ($n = 50$ within each group) and half of the children were treated without any local anaesthesia ($n = 50$ within each group) within each group. The success rate of the new robotic distraction technique was evaluated by using Parental Corah Dental Anxiety Scale, Facial Image Scale (FIS), physiological pulse rate and Frankl Behaviour Rating Scale (FBRS).

**Result:** Pulse rates, which measured during treatment and after treatment, were statistically higher in CG than in RG ($p < .05$). After dental treatment, the FIS score was significantly higher in CG than RG ($p < .05$). 88.3% of the children in RG stated that they wanted the robot to be with them at the next treatment session.

**Conclusions:** Robotic technology can successfully help in coping with dental anxiety and stress, and helps children to behave better in dental office.

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**KEYWORDS**
Children; dental anxiety; healthcare robotics; human computer interaction; iRobiQ; WoZ experimentation

## Introduction

Dental anxiety typically emerge during childhood; the associated avoidance of dental care can result in oral health problems, higher prevalence of dental caries [1], and a lower quality of life [2]. It occurs in different countries with a prevalence ranging from 5–20% [1,3]. Dental anxiety is a worldwide problem for both patients and dentists and its consequences should not be underestimated.

Paediatric dentists have used many approaches to manage dental anxiety, such as traditional behaviour management techniques like tell-show-do, voice control, positive reinforcement, and distraction [4]. Distraction techniques are non-invasive approaches that diverts children's attention from a painful stimuli and allow successful, high-quality treatment [5]. It is also easy to apply, safe and simple [6]. Visual and auditory distractions have been used in computer games, television and 3 D video glasses [7,8]. Audiovisual distraction seems to be an effective method reducing dental fear and anxiety in children compared to basic behaviour management techniques without audiovisual distraction [5,9,10]. However, Brignardello-Petersen [11] has shown that the use of audiovisual distraction does not improve behaviour or pain during dental treatment. Attar and Baghdadi [8] also showed that active distraction using an iPad demonstrated better performance than using audiovisual glasses. Therefore, there is a need to improve a new psychological approach in order to manage dental anxiety in children.

Robots have captured the interest, curiosity, and attention of children. Medical robots have only been in use for a few decades, and humanoid robots are started to be used to implement techno-psychological distraction for children in order to reduce their pain as a result of stress and anxiety during a medical procedure [12]. According to the principles of attentional capacity theory, distracting stimuli need to be stronger than pain stimulus to attract children's attention [13]. From the viewpoint of the human-robot interaction design, the clinical application of robot technologies to dental services might be good option for modern dentistry.

iRobiQ is a small, autonomous, humanoid robot manufactured by Yujin Robot. It has a touch-screen LCD display on its body, multi-colour LEDs on its face and hands allow further communication of emotions by coloured light. Programming facilitates the robot show different facial expressions such as happy, sad, surprise, or angry. In this study, iRobiQ was chosen for human facial expressions contents (humanoid emotions like sadness, jubilation, astonished

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etc.). Besides, this robot used with many years in Korean kindergartens for educational purpose [14].

The aim of this study was to use humanoid robots to implement a techno-psychological distraction technique for children between 4–10 years in order to reduce their anxiety and stress-related pain and improve their behaviour during dental treatment. The null hypotheses for this study were the following: (i) robotic accompanion does not affect anxiety scores in children; (ii) robotic accompanion does not affect children's physilogical parameters; and (iii) robotic companion do not influence children's cooperation.

## Material and methods

The following focussed question was developed in accordance with the recognised Patient, Intervention, Comparison, and Outcome (PICO) method: In children who had between 4–10 years old, first experience with the dentist and needed a restoration or a pulpotomy (P); what was the effect of techno-psychological distraction (I); compared to distraction method only (C); affect the reduction in dental anxiety by physiological and psychological considerations (O)?

### Selection and description of participants

Ethical clearance was taken from Ethical Committee of Istanbul University Faculty of Medicine (2014/461). Children were included in the study according to the following criteria; first experience with the dentist, healthy children (without any physical/mental diabilities or any systemic disease), between 4 to 10 years old, need a restoration or a pulpotomy for a primary molar, being accompanied by at least one parent, accepting to response questionnaires and take participation in the study (both by the children and parents).

### Measures

A series of questionnaires measuring anxiety and pain levels before and after treatment were administered to each child and his/her parent in order to evaluate the effects of robot accompaniance versus basic behaviour management techniques.

Parents answered Corah Dental Anxiety Scale (CDAS) before the treatment. This scale was developed by Corah and consists of four questions. A total score of 5 to 20 is obtained with this scale, scores less than 9 indicate no anxiety, scores 9–12 indicate moderate anxiety, 13–15 high anxiety, and scores above 15 indicate very high levels of anxiety [15].

Facial Image Scale (FIS) was applied after the children entered the clinic. FIS is a scale that includes five facial expressions, ranging from very unhappy to very happy, used to assess the state of children's dental anxiety (Figure 1). It is scored by giving 1 point for the most positive facial expression and 5 points for the most negative facial expression [16]. Each of the children gave their own response independently; when it was necessary, researchers helped them in

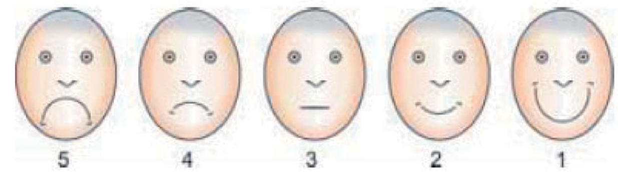


Figure 1. Facial image scale with scores from 5 to 1 [16].

reading the instructions. This questionnaire was repeated after the treatment.

One experienced paediatric dentist who was previously calibrated [intra-class correlation coefficient (ICC) score = 0.87] rated children's behaviour using Frankl's Behaviour Rating Scale (FBRS). With FBRS, the child's behaviour is classified by one of the following: definitely negative (1), negative (2), positive (3) and definitely positive (4) [17]. Children with FBRS 2, FBRS 3 and FBRS 4 scores were included in the study.

An additional question, which was 'Would you like to see the robot again in your next appointment?', were asked to the children who participated in RG.

Physiological pulse rate (bpm) was also measured using a finger type pulse oximeter (Tekin Medikal, Turkey) before, during and after treatment.

### Robot

The robot selected for this study was iRobiQ, which has been manufactured by Yujin Robot company. iRobiQ is equipped with a tablet computer that allows video and animation playback on the front panel. It can move its head, arms and wheels. With its LEDS, iRobiQ can display five types of facial expressions: disappointed, shy, neutral, surprised and happy. We integrated tooth brushing songs and dental animations by using ROCOS Studio and prepared multimedia content in Adobe Flash to motivate children with the help of the robot.

### Procedure

Before the study, the research protocol were explained to children and their parents, after the consent was granted and parental questionnaires were completed. Parents were asked to stay in the waiting room. Pre-treatment questionnaries were asked the children, then FBRS score were scored by one examiner.

All children were treated in the same clinical environment by the same dentist. The first group (CG) were treated with the help of basic guidance techniques such as tell-show-do, distraction, and positive reinforcement ($n = 100$) and the second group were treated with the robot accompaniment ($n = 100$). Half of the children were treated under local anaesthesia (infiltration anaesthesia to before restorative treatment or pulpotomy) ($n = 50$ within each group) and half of the children were treated without any local anaesthesia (superficial caries, restorative treatment) ($n = 50$ within each group) in both groups. Treatments were completed in one session. Treatment sessions were recorded with two cameras at two different locations.

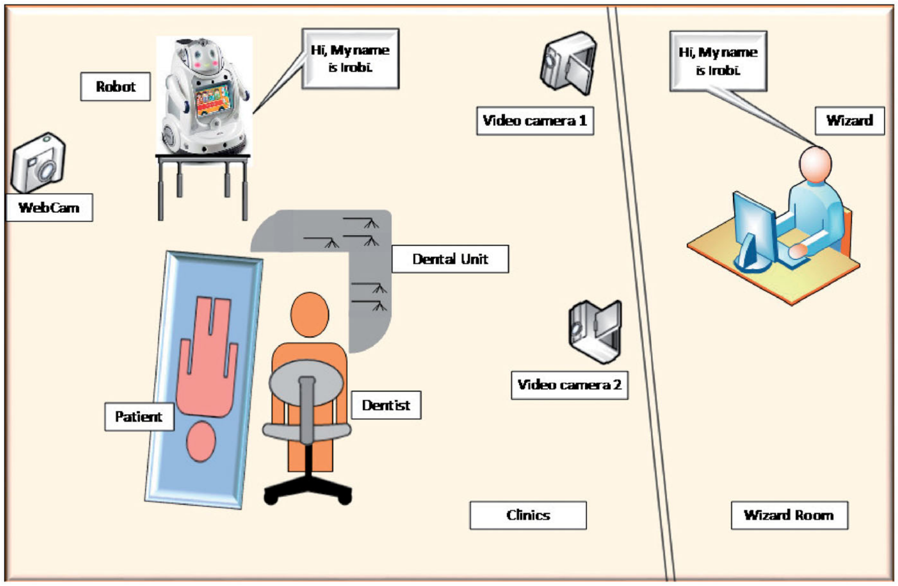


**Figure 2.** The WoZ set up.

The robot was seated on a platform, it appeared acting naturally even in the lack of autonomy. For this purpose, we used Wizard of Oz (WoZ) method, which is widely used in robot assisted studies [18]. In this method, a human operator unknown to the participants manages the robot remotely which makes it easy for children to interact with. The WoZ setup is shown in Figure 2. The first camera was placed in front of the child to record the child's facial and body expressions and behaviours, and the second camera was placed in a location to monitor the paediatric dentist, robot and child interaction. The WoZ room, far from the clinic's location, audio and video were transmitted to the WoZ room *via* a webcam with a microphone. Effective communication was achieved with WoZ. When the videos were analysed, it was seen that most of the children started to behave more natural after the robot presented some emotions in WoZ interaction. Figure 3 shows the different facial expressions and body movements of the robot.

**Figure 3.** iRobiQ performs some body movements with facial expressions during a child's dental treatment.

**Table 1.** Age and gender distribution of the study sample.

| | | n | % |
|---|---|---|---|
| Control group | Gender | | |
| | Male | 51 | 51 |
| | Female | 49 | 49 |
| | | Min–Max | Mean ± SD |
| | Age | 4–10 | 5.92 ± 1.62 |
| | | n | % |
| Robot group | Gender | | |
| | Male | 51 | 51 |
| | Female | 49 | 49 |
| | | Min–Max | Mean ± SD |
| | Age | 4–10 | 6.18 ± 1.69 |

### *Statistical analysis*

The results were analysed by using IBM SPSS Statistics 22 (IBM SPSS, Turkey). Shapiro–Wilk test was used to check the distribution of data. Comparisons between two groups were evaluated by Student t-test, Mann–Whitney U-test Paired-samples test. Paired sample test was used for in-group comparisons of normally distributed parameters and Wilcoxon signed rank test was used for in-group comparisons of non-normally distributed parameters. McNemar test was used to compare the in-group ratios. Chi square and Continuity (Yates) correction were used to compare qualitative data. Significance was evaluated at $p < .05$.

## Results

### *Sample characteristics*

Two hundred children met the inclusion criteria established for this study. One hundred children were enrolled in CG and one hundred children were enrolled in RG. The mean age of all children were 6.05 ± 1.66 years with 50% of patients were female and 49% were male in both groups. There were no significant age distribution of the children in CG and RG ($p > .05$) (Table 1). The CONSORT flow chart of participant enrolment is shown in Figure 4 [19].

### *Questionnaires*

There was no statistically significant difference between CG and RG in terms of the distribution of the anxiety levels which was assessed by CDAS ($p > .05$) (Table 2).

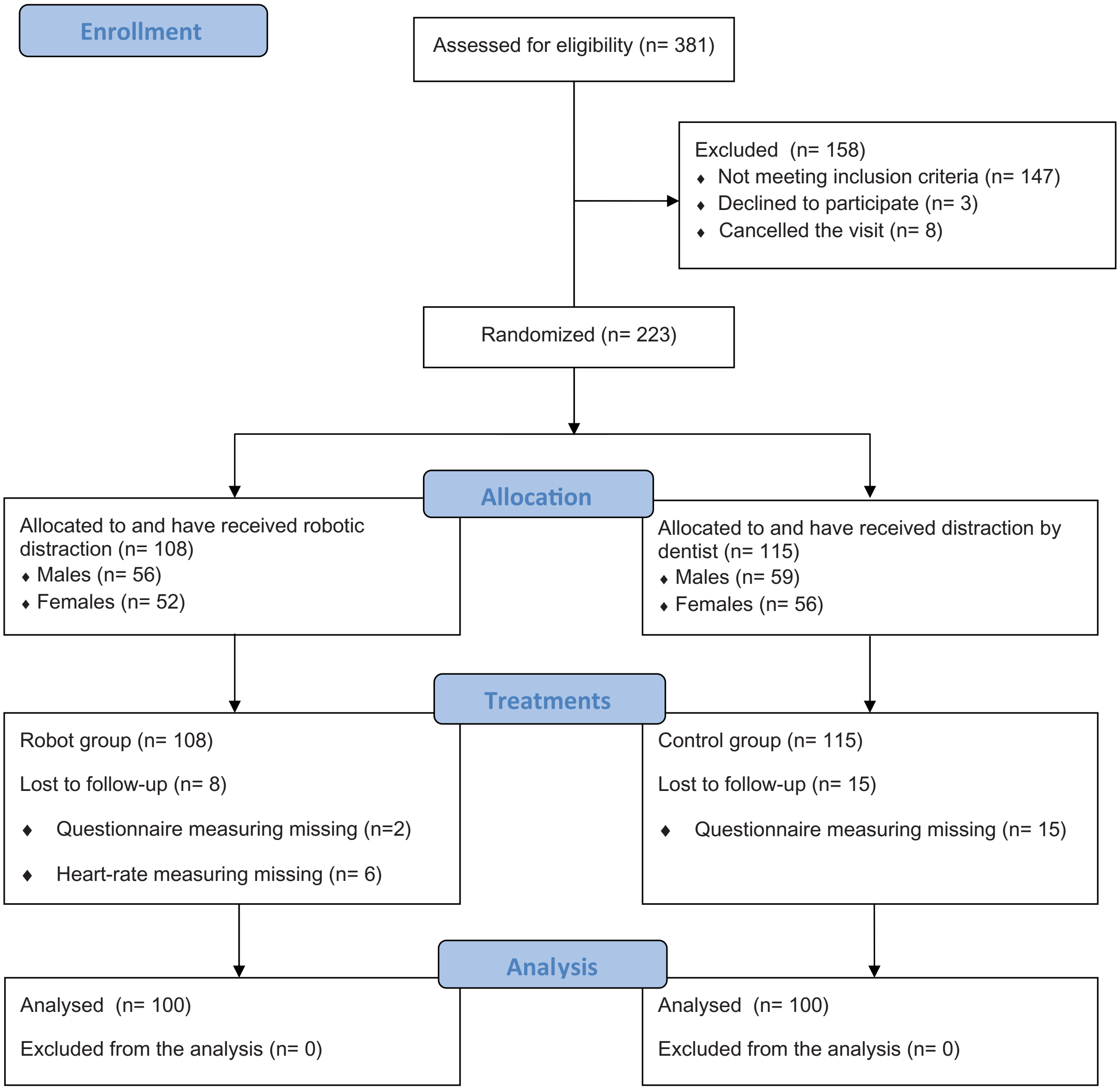


Figure 4. Consort flow chart of the patient enrolment.

Table 2. Assessment of study population level of dental anxiety before the treatment with using Corah Dental Anxiety Scale (CDAS).

| | Control group | Robot group | |
|---|---|---|---|
| CDAS | *n* (%) | *n* (%) | *p* |
| <9 | 48 (%48) | 52 (%52) | .916 |
| 9–12 | 29 (%29) | 28 (%28) | |
| 13–15 | 15 (%15) | 12 (%12) | |
| 15+ | 8 (%8) | 8 (%8) | |

Chi square test $p < .05$.

Table 3. Facial Image Scale (FIS) results in pre- and post-treatment.

| | Control group | Robot group | |
|---|---|---|---|
| FIS | Mean ± SD (Median) | Mean ± SD (Median) | $p^a$ |
| Pre-treatment | 2.13 ± 1.35 (2) | 1.84 ± 1 (2) | .328 |
| Post-treatment | 2.19 ± 1.45 (2) | 1.71 ± 1.22 (1) | .005* |
| Pre-treatment-Post-treatment $p^b$ | .819 | .109 | |

[a]Mann Whitney U test.
[b]Wilcoxon Sign Test. *$p < .05$.

Before the treatment, FIS scores were not found significantly different in both groups (p:0.328; $p > .05$). After the treatment in CG, the post-treatment FIS scores were statistically higher than the RG (p:0.005; $p < .05$) (Table 3).

### *Physiology*

The overall pulse rate was significantly lower (pre-treatment p:0.036; $p < .05$, during treatment p:0.013; $p < .05$, post-treatment p:0.001; $p < .05$) when the child was accompanied by the robot when we compare the CG. There were significant differences in terms of pulse rate during the treatment in both groups ($p < .05$). Pulse rate was found significantly different during the treatment in both groups. The mean pulse rate of the children in the CG during the treatment was significantly higher than the children in the RG (p:0.013; $p < .05$) (Table 4).

### *Behaviour*

In terms of FBRS, there is no significant differences were found in pre-treatment term (p:0.280; $p > .05$). Children in RG showed good cooperative behaviour during restorative

**Table 4.** Comparison of pulse rate of children in control and robot groups before, during and after the treatment.

| | Control group | Robot group | |
|---|---|---|---|
| Pulse | Mean ± SD | Mean ± SD | $^a p$ |
| Pre-treatment | 104.64 ± 19.24 | 99.38 ± 15.74 | .036* |
| During treatment | 110.99 ± 19.36 | 104.55 ± 17.05 | .013* |
| Post-treatment | 104.64 ± 16.96 | 97.03 ± 14.49 | .001* |
| Difference between during and pre-treatment | 6.35 ± 22.91 | 5.17 ± 18.49 | .689 |
| Difference between pre- and post-treatment | −0.32 ± 21.87 | −2.87 ± 17.49 | .384 |
| Pre-treatment – During treatment $^b p$ | .007* | .006* | |
| Pre- and post-treatment $^b p$ | .889 | .115 | |
| During treatment and post-treatment $^b p$ | .005* | .001* | |

[a]Student *t* test.
[b]Paired Sample's test. *$p < .05$.

**Table 5.** Behaviour assessment using FBRS on pre- and post-treatment.

| | | Control group | Robot group | |
|---|---|---|---|---|
| FBRS | | *n* (%) | *n* (%) | $p^a$ |
| Pre-treatment | Negative | 31 (%31) | 27 (%27) | .280 |
| | Positive | 65 (%65) | 62 (%62) | |
| | Definitely positive | 4 (%4) | 11 (%11) | |
| Post-treatment | Definitely negative | 24 (%24) | 12 (%12) | .001* |
| | Negative | 22 (%22) | 4 (%4) | |
| | Positive | 46 (%46) | 42 (%42) | |
| | Definitely positive | 8 (%8) | 42 (%42) | |
| Difference between pre- and post-treatment $p^b$ | | .001* | .001* | |

[a]Chi Square test.
[b]McNemar Test. *$p < .05$.

**Table 6.** Post-treatment behaviour scores of children.

| | Control group | Robot group | |
|---|---|---|---|
| FBRS | *n* (%) | *n* (%) | *p* |
| Positive | 15 (%15) | 46 (%46) | .001* |
| Negative | 85 (%85) | 54 (%54) | |

Positive group = (positive + definitely positive), negative group = (negative + definitely negative) according to FBRS. Yates's correction for continuity *$p < .05$.

treatment ($p < .05$). In the CG, the percentage of those who had negative FBRS after treatment (22%) was higher than that of the RG (4%), whereas the percentage of those who had absolutely positive FBRS (42%) after treatment in the RG was statistically higher than the CG (8%) (Table 5).

At the end of the treatment number of children showing positive response were found to be significantly higher (p:0.001; $p < .05$) in the RG (46%) than the CG (15%) (Table 6).

When we ask to children about their willlingness to have a robotic companion, while 75.5% of the children gave the answer 'definitely yes' in the question of 'would you want to have the robot next time you come to the clinic?', 12.8% answered 'yes', 6.4% answered 'don't know', and 5.4% answered 'no'.

## Discussion

Human-Robot Interaction (HRI) is a multidisciplinary field concerned with the 'modelling, design, implenmentation, analysis and evaluation of robots for human use' in education, work environments and public spaces, health care and therapy [20]. IRobiQ is used for cognitive training, medication reminder, telepresence communication, entertainment, and vital signs monitoring in healthcare [21]. It is also well accepted by children in early childhood educational settings [22].

For over a decade, distraction (watching movies, listening to music) has been investigated and successfully applied in clinical practice to reduce pain associated with medical procedures [23]. Several studies have reported on significant pain reduction when dental treatment is combined with a visual stimulant as a form of distraction, such as cartoons [5]. Drawing on limited attentional capacity theory [13], it is possible that cognitive-behavioral intervention will have a limited impact on reducing children's pain when these stimuli are not as intense as the painful stimulus [24]. By encouraging a patient to focus his/her attention on other thoughts, less attention is available for the pain [25]. Distraction techniques tax the patient's limited attention capacity, resulting in the withdrawal of attention away from the noxious stimulus [23]. Distractive stimulus must be stronger than pain stimulus to attract the child's attention [12]. Although, listening music and watching cartoons have shown effectiveness in reducing pain and anxiety among children undergoing a variety of medical procedures [26–28], it would appear that these distractions are not always strong enough to turn children's attention away from the pain. It is now believed that multisensory strategies, which combine visual, auditory, and tactile senses, may have a greater impact on pain than single-sensory strategies [26,27]. It has been hypothesised that the ideal distractor would require an optimal amount of attention involving multiple sensory modalities (visual, auditory, and kinesthetic) [29], active emotional involvement [30], and participation of the patient to compete with the signals from the noxious stimuli [23]. A novel method of facilitating distraction, Beran *et al.* conducted a study on children with humanoid robots to reduce the pain associated with anxiety and stress during a medical intervention [24].

The first studies on the use of robots as a distraction in the medical field are vaccination procedures. There is only one study in medicine that evaluated the use of a humanoid robot as a method of distraction for reducing distress during childhood immunizations. Interaction with a robot during vaccination resulted in significantly less pain and distress in children. The authors reported that HRI can be used as an interesting and novel method to reduce anxiety during childhood [24]. The present study showed distraction using the HRI seems to be effective in reducing self-reported dental anxiety, physiologic pulse rate and observer-rated cooperative behaviour in children during restorative treatment. Literature review shows a large amount of articles published about dental anxiety. However this is the first study to examine the effectiveness of child-robot interaction in dentistry for reducing dental anxiety during restorative treatment.

When compared to other technological behaviour management techniques in the literature, audiuvisual distraction during treatment reported less anxiety than control groups [5,31]. In recent systematic reviews, the authors suggested the use of audiovisual distraction when children need to be treated under local anaesthesia [32,33]. Researchers found that the use of audio-visual distraction during dental treatment of children is more effective than using audio distraction only [31,34]. Ram *et al.* showed that the use of audiovisual eyeglass system were more efficient than a regular television screen and it could be used instead of nitrous oxide sedation [35]. iPad found more effective than audiovisual eyeglass system in reducing dental anxiety and fear [8]. In conclusion, the reviewed studies strongly support that VR and A/V distraction are clinically viable techniques with a high potential to alleviate pain associated with different medical diagnostic and therapeutic procedures [23]. Sullivan *et al.* reported that virtual reality during dental treatment had no significant effect on the behaviour or anxiety but significantly reduced the pulse [36].

The present study showed that the post-treatment FIS scores were statistically higher in the CG than the RG. Based on these results, it is seen that children's anxiety level increases in CG, whereas children in RG have less anxiety after dental treatment. It is found that interacting with iRobiQ decreased self-reported dental anxiety in comparison with children treated by dentist skills alone.

The mean pulse rate of the children in the the CG during the restorative treatment was significantly higher than the children in the RG. Results of RG show that human-robot interaction provides a significant reduction in dental anxiety. This result complements other studies that reported less increase in pulse rate in a group of children undergoing dental treatment with audio-visual distraction methods [5,34,37–39].

At the end of the treatment session, number of children showing positive response were found to be significantly higher in the RG than the CG according to FBRS. Comparing the children's willingness to the dental treatment, which was evaluated by the dentist, the children in RG showed positive behaviour after treatment than they did have before treatment. The results reflected positive effects of robot-mediated distraction with higher success outcomes than dentist-mediated distraction.

As in the study of Beran *et al.* [24] the question of 'Would you want to have the robot next time you come to the clinic?' showed children enjoyed and liked the presence of the robot during dental treatment. Most of children in this study showed clear interest in iRobiQ and responded this question with positive attitude, iRobiQ engaged children in their treatment and maintained their interest.

In this study, we proposed a robotic behaviour management technique as a useful adjunct in dental offices to help reduce anxiety, discomfort, boredom, and the time required to perform routine dental treatments. Therefore, the null hypothesis can be rejected. The present study also provides encouraging initial support for the use of robots for controlling anxiety during painful dental procedures. Humanoid robots show promise of reducing procedural pain and distress in children during dental treatment.

However, the most important disadvantage of the system we recommend is the high cost of the robot. One of the limitation of this technique, whether if the robot damaged on a hardware or software basis, they must be examined by a qualified specialist. Maintanence of comprehensive robotic systems also requires high budgets. In this project, we plan to transfer our experiences during the interaction of robotic systems with the patient to a mobile application that will run on extremely low-cost virtual reality glasses and can be easily downloaded from the mobile application store (Google Play and App Store) and installed easily. In this way, we aim to reduce the cost of the technology.

## Disclosure statement

No potential conflict of interest was reported by the author(s).


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