The effects of music listening during extraction of the impacted mandibular third molar on the autonomic nervous system and psychological state

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Abstract

Purpose. Pain, anxiety, and nervousness related to dental procedures can cause acute changes in the autonomic nervous system. Music is widely accepted as a relaxation method during dental treatment; however, its effects during dental treatment are unclear. We explored the effects of music listening during extraction of the impacted mandibular third molar on the autonomic nervous system and the psychological state, and hypothesized that music listening would suppress sympathetic nervous activity and reduce anxiety.

Methods. In this prospective study, 40 patients scheduled for extraction of an impacted mandibular third molar were randomized into two groups: extraction without music (control group) and extraction with music listening (music group). Heart rate variability was recorded during the experiment, and the Modified Dental Anxiety scale (MDAS) and the State-Trait Anxiety Inventory (STAI) scores were recorded pre-and post-procedure. Descriptive and bivariate statistics were computed and the p-value was set at 0.05.

Results. An increased low frequency/high frequency ratio (LF/HF) was observed in

the control group during incision and reflection of flap, bone removal, and separation of the tooth crown; the ratio was significantly decreased in the music group during these time points ($p<0.05$). Compared to the control group, the music group had a significantly greater decrease in postoperative STAI state anxiety (STAI-S) scores from the preoperative levels ($p<0.05$).

Conclusions. Our study suggested that music listening while undergoing extraction of the impacted mandibular third molar suppresses the activity of the sympathetic nerves during incision, reflection of flap, bone removal, and separation of the tooth crown and relieves anxiety after treatment. Future studies will focus on studies of the mechanisms involved, and methods to prevent the onset of systemic incidents.

Introduction

The pain, anxiety, and nervousness related to dental treatment can cause acute changes in the autonomic nervous activity. Acute fluctuations in the activity of the autonomic nervous system affect circulatory dynamics and cause complications such as increased blood pressure and vagal reflex.[1,2] Therefore, monitoring changes in the autonomic nervous activity during dental treatment may be useful in preventing complications.

In recent years, heart rate variability (HRV) analysis has been reported to be useful for monitoring the autonomic nervous activity during dental treatment.[3-5] HRV can noninvasively monitor and quantify real-time changes in the autonomic nervous activity during dental treatment.[6] HRV represents a fluctuation in the sinus node ignition period; it is measured as a variation of the RR interval on the electrocardiogram, and is resolved into components by spectrum analysis. A frequency ranging from 0.04 Hz - 0.15 Hz is defined as the low frequency (LF) component, and a frequency of 0.15 Hz or more is defined as the high frequency (HF) component. The LF component reflects both sympathetic and parasympathetic nervous activity, while HF originates from the activity

of the parasympathetic nerves. Therefore, LF/HF indicates sympathetic nervous activity.[6]

Anxiety and tension can cause complications; music is widely used for alleviating anxiety and tension during dental treatment.[7-11] The effect of music on the autonomic nervous system has been studied since a long time; however, there is no consensus on the effect of music on the autonomic nervous system.

Dental extraction is very stressful for patients. Among the tooth extractions, extraction of the mandibular third molar causes the most anxiety.[5,12,13] A previous study examined the usefulness of music therapy during endodontic treatment[3]; however, as far as the authors are aware, there is no research regarding the usefulness of music listening during dental extraction.

Therefore, in this study, we objectively evaluated and analyzed the effect of music listening during extraction of the impacted mandibular third molar on autonomic nervous activity, circulatory dynamics, and the psychological state.

Methods

Ethical approval

The present study protocols were approved by the Clinical Research Ethics Review Committee of Kagoshima University Hospital (No.170257). Informed consent was obtained from all subjects. This study followed the Declaration of Helsinki on medical protocol and ethics.

Subjects

The study was conducted in 40 female patients, aged 20 to 40 years, who were scheduled for impacted mandibular third molar extraction between March 2018 and September 2018 at Kagoshima University Hospital. We determined the required sample size by power analysis ($\alpha = 0.05$, $\beta = 0.2$). Subjects were randomly assigned to one of two groups, namely, the control group and the music group using the sealed envelope method. The patients did not have a history of cardiovascular disorders, diabetes mellitus, or other disorders known to affect the autonomic nervous system. They were non-smokers and not on any regular medication. The patients were required to avoid alcohol and caffeine-containing beverages for 24 hours prior to study commencement,

and to avoid eating or exercising 6 hours before beginning the study.[14-17]

Experimental environment

The study was performed in a clinic room, free from other noises, and the temperature was maintained at 24℃.[14] Subjects lay in a supine position on the dental chair, and the procedures were performed at 2:00 pm to minimize the effects of circadian rhythm.[14,17] Headphones were used in all procedures and the subjects closed their eyes. Blood pressure monitoring was carried out throughout the procedure.

Protocol

The HRV of the subjects was recorded during the procedure. The Modified Dental Anxiety Scale (MDAS) and the State-Trait Anxiety Inventory (STAI) questionnaires were used to evaluate anxiety levels pre- and post-procedure (Fig. 1). Headphones were used in all subjects, and dental treatment was started after resting for 15 minutes. In the music group, subjects were treated while listening to music. The music (Symphony No. 2 in E minor, Op. 27th–3rd Movement, Adagio, by Rachmaninov) was played to the subjects via headphones. The subject's respiratory rate was counted visually during the procedure.

Heart rate variability analysis

HRV was calculated every two seconds by the software MemCalc-Makin2 (GMS, Tokyo, Japan) via an electroencephalographic monitor MWM01 (GMS, Tokyo, Japan). LF, HF, LF/HF, and heart rate (HR) were used as HRV parameters.

Changes in circulatory dynamics

Systolic blood pressure (SBP) was used as an indicator of circulation. Noninvasive blood pressure measurement was performed every 2 minutes.

Analysis points

Analysis of the autonomic nervous activity was started after the subjects were kept in a resting state for 15 minutes. Based on past reports,[6,15,17] we used the measurements obtained for 5 min after a 15 min rest period as resting data.

Based on the study procedures in earlier reports, autonomic nervous activity and circulatory dynamics were analyzed in this study for each procedure, namely, local anesthesia injection, incision and reflection of flap, bone removal, separation of the tooth crown, and suturing.[4]

Questionnaire analysis

The MDAS questionnaire consisted of five questions to evaluate dental anxiety: 1) "If you went to your dentist for treatment tomorrow, how would you feel?", 2) "If you were sitting in the waiting room (waiting for treatment), how would you feel?", 3) "If you were about to have a tooth drilled, how would you feel?", 4) "If you were about to have your teeth scaled and polished, how would you feel?", and 5) "If you were about to have a local anesthetic injection in your gum, above an upper back tooth, how would you feel?" The answer to each question was scored on a scale that ranged from "not anxious" (score 1) to "extremely anxious" (score 5).

The STAI consisted of 40 self-reporting items evaluating conscious awareness of the effects of anxiety. The anxiety effects were labeled as either state anxiety (STAI-S) or trait anxiety (STAI-T).[7]

Statistical analyses

For statistical analysis, the Mann-Whitney U test, the chi-square test, the Friedman test, and the Steel-Dwass test were used. P-values less than 0.05 were considered statistically significant. Statistical analysis was performed using GraphPad Prism, version 6 (San Diego, California).

Results

Subjects

The study was planned among 40 female patients. However, 6 women in each group were excluded because of alteration of the treatment plan (for example, extraction of the maxillary molar tooth was added) or due to patients deciding not to go ahead with the procedure. Finally, the number of subjects in each group was 17 and the final total number of subjects was 34 (Fig. 2).

The mean age, height, and weight of the subjects are indicated in Table 1. There were no significant differences in the physical characteristics of the patients in the two groups. The volume of local anesthetics used, the treatment time, and the side on which treatment was performed are indicated in Table 1. There were no significant differences with regard to these treatment-related parameters. The pre-treatment MDAS, STAI-S and STAI-T scores are indicated in Table 1. There were no significant differences with regard to the psychological state of the patient prior to the procedure.

MDAS and STAI-S scores and LF/HF pre-procedure

A moderate positive correlation was observed between MDAS and preoperative

STAI-S scores in all patients. (Correlation coefficient: 0.617; $p<0.01$). There was a moderate positive correlation between MDAS scores and LF/HF at rest (Correlation coefficient 0.58, $p<0.01$) (Fig. 3).

Relative ratios of LF/HF

The LF/HF results were expressed as relative ratios of LF/HF at specific time points (administration of local anesthesia, incision, reflection of flap, bone removal, separation of the tooth crown, and extraction) to that at rest. In the control group, a significant increase in LF/HF was observed during administration of local anesthesia, incision, reflection of flap, bone removal, separation of the tooth crown, and extraction compared with that at rest. In the music group, a significant increase in LF/HF was observed during administration of local anesthesia and extraction compared with that at rest.

Compared with the control group, it was observed that the LF/HF was significantly decreased in the music group during incision, reflection of flap, bone removal, and separation of the tooth crown (Fig. 4a)

Relative ratios of HF

HF data are expressed as relative ratios of HF at specific time points (administration

of local anesthesia, incision, reflection of flap, bone removal, separation of the tooth crown, and extraction) to that at rest. No significant within-group differences were observed during local anesthesia, incision and reflection of flap, bone removal, separation of the tooth crown, extraction, or suturing in the control and music groups. No significant between-group differences were observed at rest, during local anesthesia, incision and reflection of flap, bone removal, separation of the tooth crown, extraction, or suturing between the control and music groups (Fig. 4b).

Relative ratios of HR

HR data are expressed as relative ratios of HR at specific time points (administration of local anesthesia, incision, reflection of flap, bone removal, separation of the tooth crown, and extraction) to that at rest. No significant within-group differences were observed at rest, during local anesthesia, incision and reflection of flap, bone removal, separation of tooth crown, extraction, or suturing in the control and music groups. No significant between-group differences were observed during local anesthesia, incision and reflection of flap, bone removal, separation of the tooth crown, extraction, or suturing between the control and music groups (Fig. 4c)

Relative ratios of SBP

SBP results were expressed as relative ratios of SBP at specific time points (administration of local anesthesia, incision, reflection of flap, bone removal, separation of the tooth crown, and extraction) to that at rest. In the control group, a significant increase in SBP was observed during local anesthesia, incision and reflection of flap, bone removal, separation of the tooth crown, extraction, and suturing, compared with that at rest.

In the music group, a significant increase in SBP was observed during local anesthesia, incision and reflection of flap, bone removal, separation of the tooth crown, and extraction, compared with that at rest (Fig 4d).

Postoperative STAI state anxiety scores

Compared to the control group, the music group had a significantly greater decrease in postoperative STAI state anxiety scores from preoperative values ($p=0.047$) (Fig. 5).

Discussion

The main finding of this study was that sympathetic nervous activity was suppressed during incision and reflection of flap, bone removal, and separation of the tooth crown with music listening while undergoing extraction of the mandibular third molar.

Some previous studies have conducted research on the autonomic nervous activity during tooth extraction; however, the type of the extracted tooth and the experience of the surgeon in these reports was not standardized. Therefore, our study targeted extraction of the mandibular third molar. We expected that the stress level of the patient undergoing treatment would be different based on the level of experience of the surgeon. All extractions in this study were performed by the same surgeon, and thus, we standardized the operating conditions and the procedure of tooth extraction.

Local anesthetic combined with adrenaline was used in the studies that reported HRV during injection of local anesthesia.[18] However, adrenaline affects the circulation and the HRV.[18] Therefore, we used local anesthesia with 3% prilocaine with felypressin, and a catecholamine was not used.

The music (Symphony No. 2 in E minor, Op. 27-3rd Movement, Adagio, by

Rachmaninov) was selected, based on previous reports, for two reasons: 1) music tempo does not stimulate the sympathetic nervous system,[19] and 2) classical music enhances subject relaxation. It has been reported that neither the HR, LF/HF, nor HF was affected by a music tempo of 60 beats per minutes (bpm).[19] Moreover, the LF/HF was found to significantly increase in response to music listening at a music tempo of 100 bpm or more.[20] The music tempo used in this study was equivalent to about 58 bpm, and thus, was not expected to stimulate the sympathetic nervous system and affect HR.

In addition, classical music is widely used in dentistry to relax patients,[8,11] and has been shown to significantly reduce patient anxiety during dental treatment.[7,11] Classical music is believed to affect physiological and psychological responses.[21-26]

Measurement of HRV is commonly used to measure activity of the autonomic nerves. As with past reports,[4] we thought that the LF/HF would be able to quantify the stress response during tooth extraction effectively in this study.[4] In addition, the respiratory rate was 9 or more, and therefore, we could accurately assess parasympathetic nervous activity.[27] This study protocol was considered appropriate for evaluating the autonomic nervous system.[23]

The MDAS and STAI scales are widely used to evaluate anxiety and fear of dental treatment.[25] In this study, we found that there was no significant difference between the groups with regard to all the preoperative psychological tests. Thus, the 2 groups were appropriately assigned. A correlation was found between the MDAS and STAI-S scores before dental treatment, which implied the usefulness of the MDAS questionnaire (with fewer questions). There was a correlation between the pre-treatment MDAS and LF/HF values after 15 to 20 minutes of rest in all patients. In past reports, a bilateral correlation was observed between psychology and the autonomic nervous system.[28] Therefore, we thought that the pre-treatment MDAS would be useful in predicting the sympathetic nervous activity before the start of treatment.

The process from local anesthesia injection to tooth removal increased the LF/HF compared with the resting state in the control group, and the LF/HF was significantly decreased during the process of incision and reflection of flap, bone removal, and separation of the tooth crown in the music group. However, listening to music during local anesthesia injection and tooth extraction did not decrease the LF/HF. In order to perform bone removal and separation of the tooth crown, instruments with high-speed

rotation are needed; thus, iatrogenic noise due to dental treatment is generated. We suggest listening to classical music via headphones to reduce the sympathetic nervous stimulation resulting from dental treatment noise.

Except during local anesthesia and extraction of the mandibular third molar, the LF/HF was decreased by music listening, for example, at incision and reflection of flap. We suggest that music listening is partly useful even in procedures that do not involve noise. Since dental treatment is performed in an environment involving noise, music listening is considered useful, and this process may also be useful in some treatments that do not involve a noise-filled environment. Our results showed the usefulness of music listening, which suppresses sympathetic activity during the processes of incision and reflection of flap, bone removal, and separation of the tooth crown in extraction of the impacted mandibular third molar.

In addition, the HF did not show any significant difference in both groups. This might be because there are individual differences in the autonomic nervous system; there may have been individual differences in the response of the parasympathetic nervous system during stimulation of the sympathetic nervous system. Although heart rate is determined

by the balance between the sympathetic and parasympathetic nervous activities, the autonomic nervous system of human beings is dominated by the parasympathetic nervous system.[29] This might be the reason that there was no significant change in HR despite sympathetic nervous stimulation.

Sympathetic nerves are distributed not only in the sinus node but also in the myocardium; these nerves increase the myocardial contractile force and cardiac output, and cause a change in the circulatory dynamics. Blood pressure is determined by the relationship between the cardiac output and the peripheral vascular resistance, and therefore, cardiac sympathetic nervous activity and blood pressure are not necessarily correlated. As per past reports, cardiac sympathetic nervous activity may be reflected in the internal stress level of a patient, and not necessarily be reflected on blood pressure and heart rate.[4] Our results implied that music listening during the treatment process can suppress internal stress. In addition, compared with the control group, the degree of reduction in STAI state anxiety scores from the rest period was significantly greater in the music group ($p=0.047$). Therefore, we suggest that music listening during extraction of the impacted mandibular third molar is highly effective in reducing anxiety scores of

the patient.

This study had some limitations. We only targeted female subjects. Moreover, the procedure was limited to tooth extraction of the impacted mandibular third molar. Further work is required to evaluate the mechanisms involved and the methods to prevent the onset of systemic incidents.

Conclusions

Our study suggests that that the LF/HF can reflect internal stresses during extraction of the impacted mandibular third molar. The pre-treatment MDAS score predicted the state of the sympathetic nervous system before the operation started. Music listening while undergoing extraction of the impacted mandibular third molar suppresses sympathetic nervous activity during incision and reflection of flap, bone removal, and separation of the tooth crown, and relieves anxiety.

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Table 1

Comparison of physical and mental characteristics of the subjects and factors related to surgery between the two groups

	Control (n=17)	Music (n=17)	Total (n=34)	p
Age (years)	27.94±6.05	27.47±6.52	27.70±6.2	0.81
Height (cm)	157.47±5.21	154.71±6.42	156.09±5.92	0.14
Weight (kg)	53.76±11.22	48.8±7.14	51.28±9.59	0.18
Local anesthesia (mL)	5.05±1.06	5.63±0.98	5.34±1.05	0.15
Operation time (min)	35.71±9.73	41.4±11.07	38.56±10.67	0.13
Side (Left/Right)	9/8	5/12	14/20	0.16
MDAS scores	13.17±4.37	16.11±5.27	14.64±5.01	0.08
STAI-S scores	48.35±8.27	51±11.19	49.67±9.78	0.32
STAI-T scores	56.88±9.41	56.17±8.51	56.53±8.84	0.85

MDAS: Modified Dental Anxiety scale; STAI-S: State-Trait Anxiety Inventory – State anxiety; STAI-T: State-Trait Anxiety Inventory – Trait anxiety

Figure Legends

Figure 1. Time course of the procedure in the control and music groups.

BP: Blood pressure; HR: Heart rate; HRV: Heart rate variability

Figure 2. Study design

Figure 3. Correlation between MDAS scores and LF/HF at rest.

$p<0.01$; Correlation coefficient $r=0.58$

LF/HF: Low frequency/high frequency ratios; MDAS: Modified Dental Anxiety scale

Figure 4

a. Comparison of low frequency/high frequency ratios (LF/HF) during extraction of impacted mandibular third molar between the control and music groups and within each group at each stage.

Data represent means and standard errors. Statistical significance: Comparison between groups: ∗ $p<0.05$, ∗∗ $p<0.01$, Comparison among groups: control † $p<0.05$, ‡

p<0.001 (vs. Rest); music || p<0.01 (vs. Rest), § p<0.01 (vs incision and flap).

b. Comparison of the high frequency (HF) component during extraction of the impacted mandibular third molar between the control and music groups and within each group at each stage.

Data represent means and standard errors.

c. Comparison of heart rate (HR) during extraction of the impacted mandibular third molar between the control and music groups and within each group at each stage.

Data represents means and standard errors.

d. Comparison of systolic blood pressure (SBP) during extraction of the impacted mandibular third molar between the control and music groups and within each group at each stage.

Data represent means and standard errors. Statistical significance: Comparison between groups: ∗ p<0.05, ∗∗∗ p<0.01,

Comparison among groups: † p<0.05, ‡ p<0.001 (vs. rest).

Local: Local anesthetic injection; Separation: Tooth crown separation; Extraction: Extraction of the impacted mandibular third molar

Figure 5. Comparison of decrease in the State Anxiety Inventory (STAI-S) scores pre- and post-experiment in the control group and the music group.

Data represent means and standard errors. Statistical significance: *p<0.05.

Table and Figure

Table 1

Comparison of physical and mental characteristics of the subjects and factors related to surgery between the two groups

	Control (n=17)	Music (n=17)	Total (n=34)	p
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Operation time (min)	35.71±9.73	41.4±11.07	46.76±13.12	0.13
Side (Left/Right)	9/8	5/12	14/20	0.16
MDAS scores	13.17±4.37	16.11±5.27	14.64±5.01	0.08
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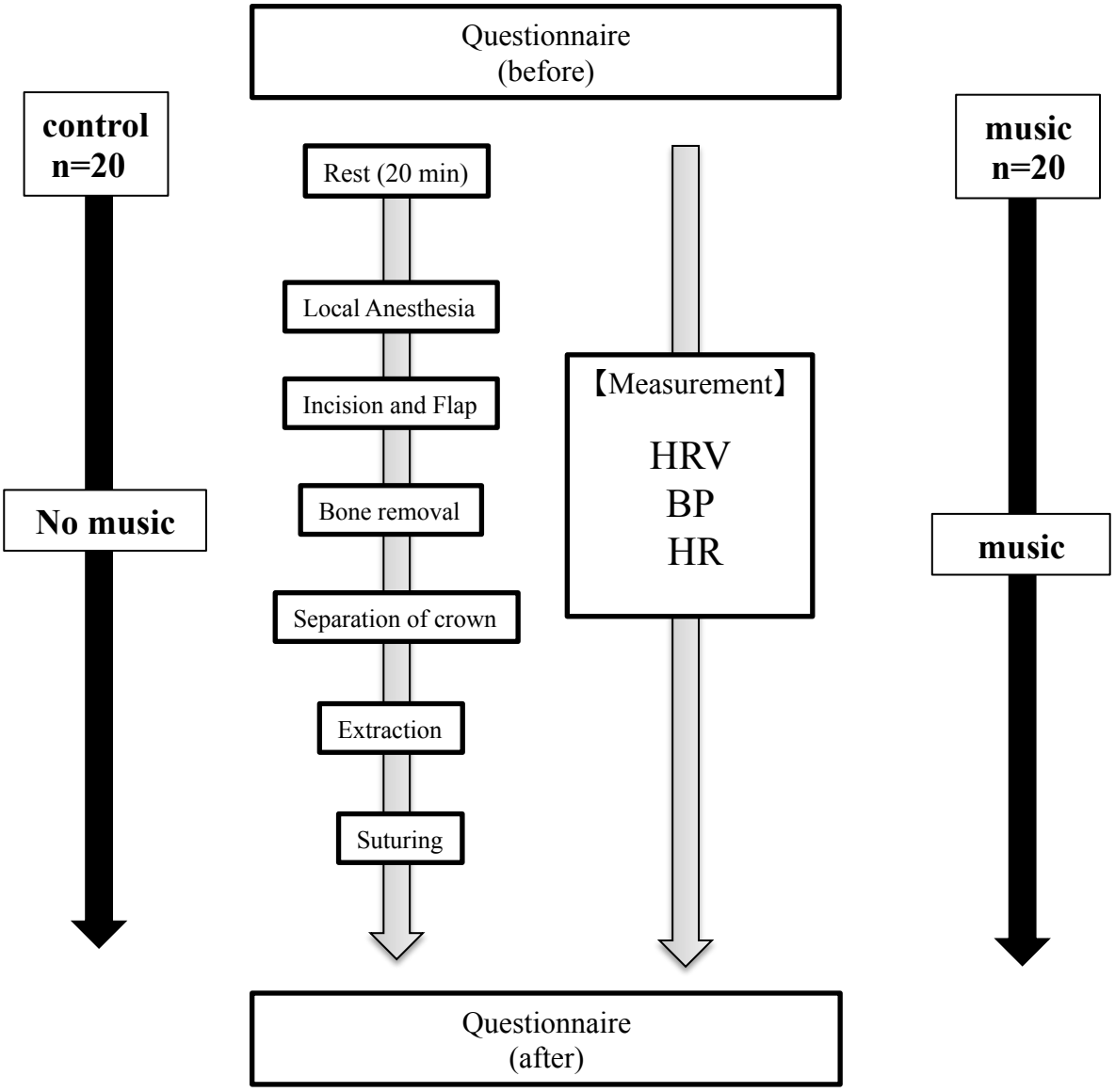
Fig. 1



HRV	Heart Rate Variabiliy
LF/HF	Low frequency/High frequency (Sympathetic nervous activity)
HF	High frequency (Parasympathetic nervous activity)
HR	Heart rate
SBP	Systolic blood pressure
MDAS	Modified Dental Anxiety Scale
STAI-S	State Anxiety Inventory
STAI-T	Trait Anxiety Inventory

Figure 1. Time course of the procedure in the control and music groups. BP: Blood pressure; HR: Heart rate; HRV: Heart rate variability

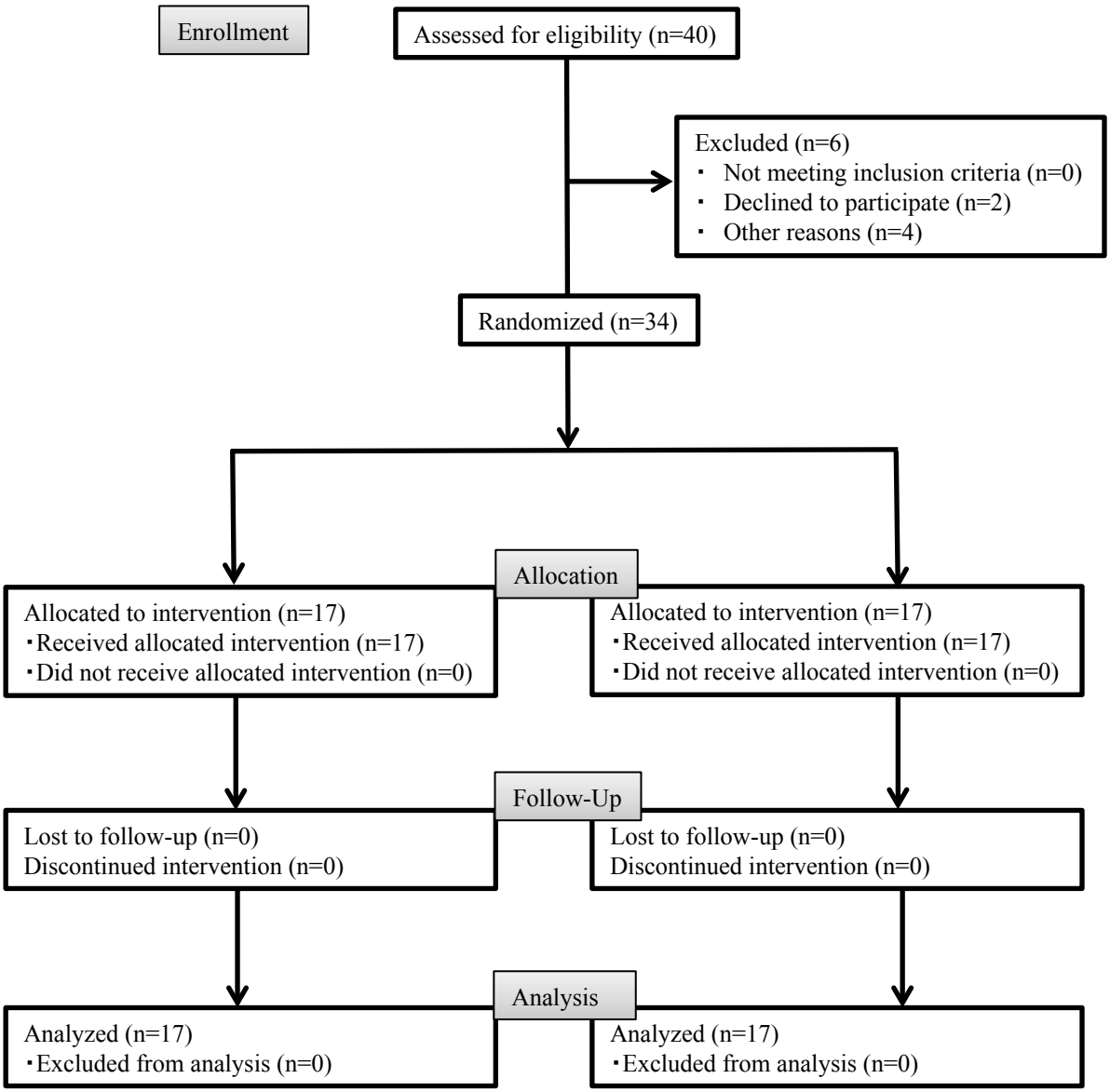


Figure 2. Study design

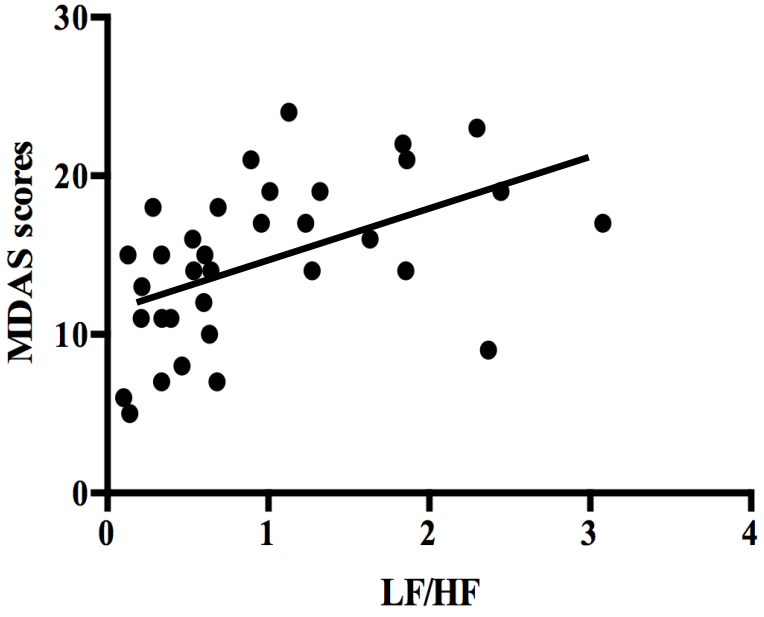


Figure 3. Correlation between MDAS scores and LF/HF at rest. $p<0.01$; Correlation coefficient $r=0.58$

LF/HF: Low frequency/high frequency ratios; MDAS: Modified Dental Anxiety scale

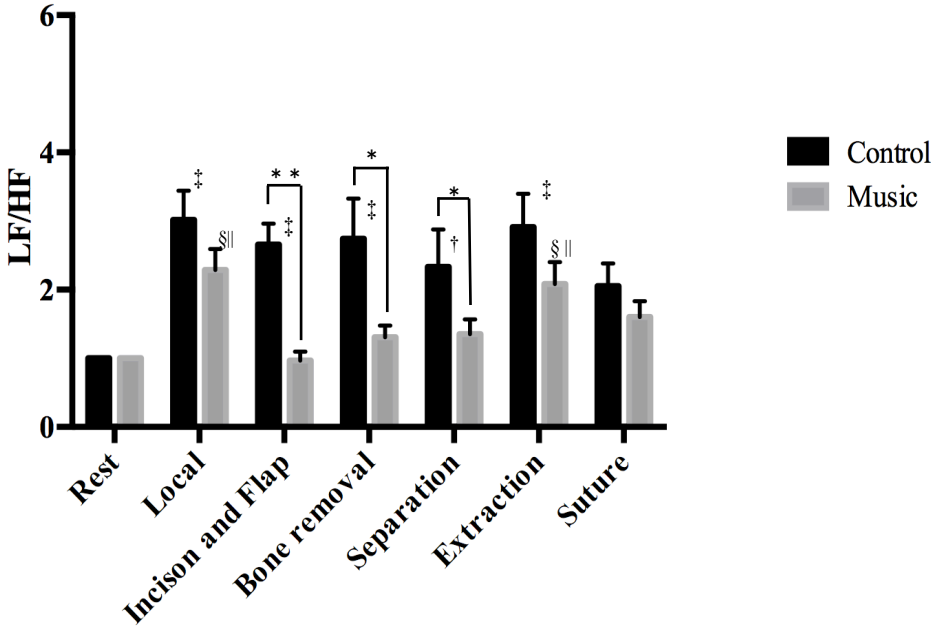


Figure 4a. Comparison of low frequency/high frequency ratios (LF/HF) during extraction of impacted mandibular third molar between the control and music groups and within each group at each stage. Data represent means and standard errors.
Statistical significance:
Comparison between groups: * $p<0.05$, ** $p<0.01$,
Comparison among groups: control † $p<0.05$, ‡ $p<0.001$ (vs. Rest); music || $p<0.01$ (vs. Rest), § $p<0.01$ (vs incision and flap).
Local: Local anesthetic injection; Separation: Tooth crown separation; Extraction: Extraction of the impacted mandibular third molar

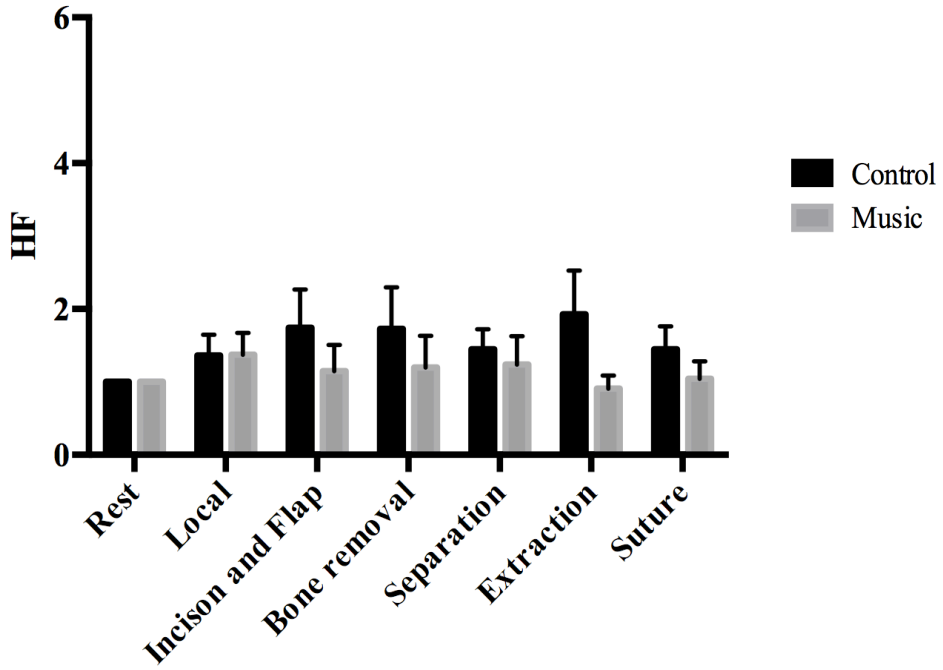


Fig4b. Comparison of the high frequency (HF) component during extraction of the impacted mandibular third molar between the control and music groups and within each group at each stage. Data represent means and standard errors.
Local: Local anesthetic injection; Separation: Tooth crown separation; Extraction: Extraction of the impacted mandibular third molar

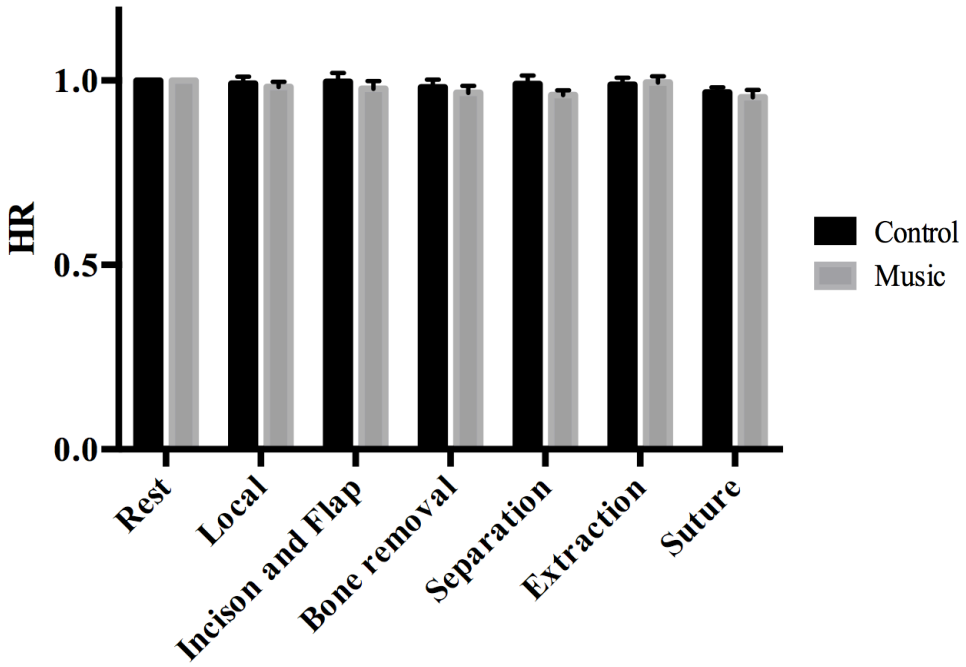


Fig4c. Comparison of heart rate (HR) during extraction of the impacted mandibular third molar between the control and music groups and within each group at each stage. Data represents means and standard errors.
Local: Local anesthetic injection; Separation: Tooth crown separation; Extraction: Extraction of the impacted mandibular third molar

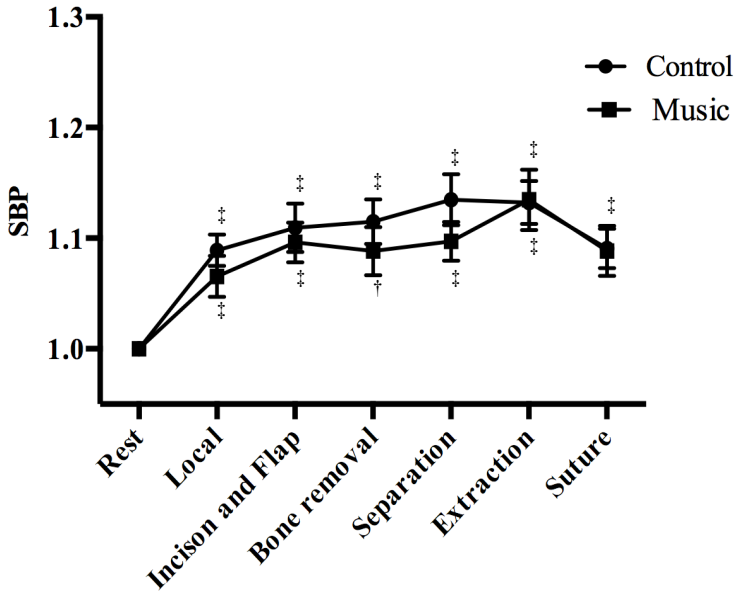


Fig4d. Comparison of systolic blood pressure (SBP) during extraction of the impacted mandibular third molar between the control and music groups and within each group at each stage.
Data represent means and standard errors. Statistical significance: Comparison between groups: * $p<0.05$, ** $p<0.01$,
Comparison among groups: † $p<0.05$, ‡ $p<0.001$ (vs. rest).
Local: Local anesthetic injection; Separation: Tooth crown separation; Extraction: Extraction of the impacted mandibular third molar

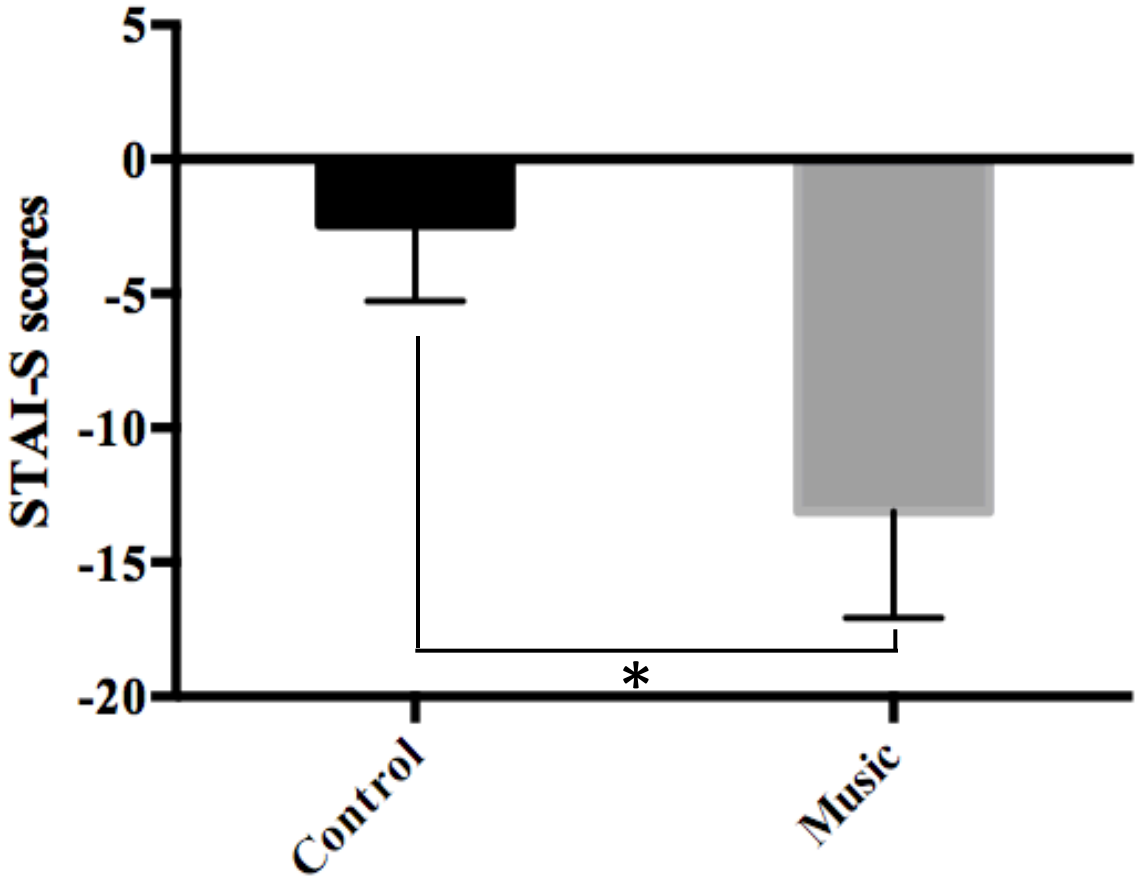


Figure 5. Comparison of decrease in the State Anxiety Inventory (STAI-S) scores pre- and post-experiment in the control group and the music group.
Data represent means and standard errors. Statistical significance: *$p<0.05$.