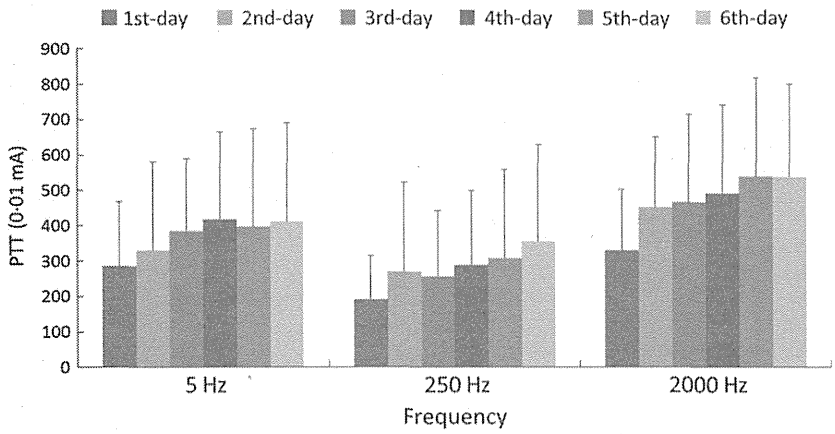

Fig. 2. Pain tolerance threshold (PTT) measurements of 6 days. The PTTs measured when the different frequencies were administered in different orders were approximately the same. The Cronbach's coefficient α calculated by PTTs at 5, 250 and 2000 Hz in a day was 0·91, 0·87 and 0·90, respectively.

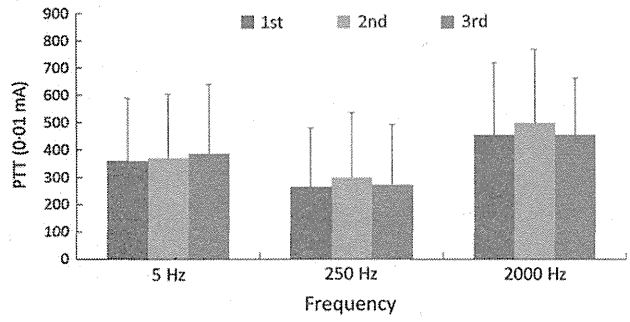

Fig. 3. Pain tolerance thresholds (PTTs) obtained when the different frequencies were administered in different orders. The PTTs measured when the different frequencies were administered in different orders were approximately the same. The Cronbach's coefficient α calculated by PTTs at 5, 250 and 2000 Hz in a day was 0·91, 0·87 and 0·90, respectively.

Table 1. Effect of frequency and gender on pain tolerance threshold (PTT) values

	5 Hz	250 Hz	2000 Hz
Male	420·0 (78·9)	327·3 (262·2)	498·6 (272·2)
Female	322·8 (84·5)	230·2 (89·6)	440·4 (175·0)
Total	371·4 (80·4)	278·7 (197·1)	469·4 (224·7)

The three-way repeated measures ANOVA showed that the current frequency affected PTT ($P < 0·01$) but gender did not ($P > 0·05$).

from one measurement to the next, with regard to PTT as measured in this study.

Table 1 summarises the PTTs by current frequency and gender. The three-way repeated measures ANOVA showed that current frequency affected PTT ($P < 0·01$) but gender did not ($P > 0·05$).

Discussion

In this study, PTT measurements derived from the alveolar ridge using an electrical current stimulus generated by an electro-diagnostic device exhibited excellent reliability. Thus, the technique would be useful in the clinical setting. The reliability of the measurements was mainly confirmed by consistency testing via Cronbach's coefficient α, the acceptable range of which is from 0·70 to 0·95 (13, 14). All the alpha values of the TPP measurements taken at 5, 250 and 2000 Hz were more than 0·95, which translates to excellent reliability, given an acceptance threshold of 0·80.

Additionally, we confirmed that there was no carry-over effect from one measurement to the next, under the parameters of this study, verifying this was important, to confirm the validity of the reliability tests. After taking each individual PTT measurement, and before taking the next, the targeted area was checked using a dental mirror, and the participant was asked whether they still felt any residual irritation from the stimulus they had just received. This checking method is sufficient when measuring PTTs in the manner described herein, because evidently there was no carry-over effect.

The PTTs obtained on the first day were significantly lower than those obtained on subsequent days. Most participants told the operator that on the first day when the stimulus was applied to the oral mucosa they immediately released the button to discontinue the stimulus, as an instinctive or impulsive reaction an unfamiliar stimulus, despite explanations as to what they would experience being provided to

them prior to the test. This observation is concordant with previous reports that psychological factors affect the perception of pain (3, 7). Those reports, and the current study, suggest that verbal explanation alone is not sufficient for negating the startling reflex that results from an unfamiliar stimulus involving pain. It was concluded that the operator should expose the participants to each of the three frequencies used to assess PTT, prior to administering the actual PTT test; allowing them to experience the frequencies prior to the actual test may negate the startle reflex.

The increasing PTTs gradually became constant over time. This phenomenon may be attributable to habituation to painful stimulation, that is, an adaptive response to repeated painful stimulation. There have been many reports on habituation to painful stimulation. Bingel *et al.* (15) evaluated changes in pain processing and perception in response to a thermode-induced heat stimulus over time and reported increasing pain thresholds and decreasing pain ratings. Nickel *et al.* (16) identified central components associated with habituation to repetitive painful electrical stimuli. Okayasu *et al.* (17) reported habituation to pain induced by mechanical stimuli. Habituation appears to be non-specific with regard to the type of pain, and it is observed in different sensory modalities and organs. The change in PTT more than 6 days observed at the alveolar ridge in response to electrical stimuli agreed with these previous reports relating to pain induced by several different modes of stimulation.

The electrical current stimulus imparted by the electro-diagnostic device used in this study had no side effects on the oral mucosa. It was confirmed that the stimulus administered via this equipment can induce unique pain perception without injury to the oral mucosa and that it is effective when used to conduct a PTT study. We will initiate a study to investigate correlations between PTTs to electrical stimulus and denture wearers' clinical outcomes after fitting of new dentures, including parameters such as complaints of pain, number of sore spots on the alveolar ridge, number of visits for denture adjustments and satisfaction ratings. The electrical stimulus from the device that we plan to use in this future study can stimulate almost every sensory nerve, including the A-delta fibres and C fibres that respond to mechanical stimuli induced by dentures. Therefore, this subsequent study is expected to aid dentists in predicting which patients might have problems wearing dentures.

Conclusion

This study suggests that PTT measurements derived by applying an electrical current to the alveolar ridge using an electro-diagnostic device exhibit excellent reliability, and thus, the method is a practical option for PTT measurement in the clinical setting.

Acknowledgments

This study was conducted in accordance with the Declaration of Helsinki, and each subject received oral and written information about the study and provided informed consent. The study protocol was reviewed and approved by the Human Ethics Committee of Nihon University School of Dentistry at Matsudo (EC 12-12-003-2). This research was carried out without funding. There are no conflict of interests to declare.

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