〔ORIGINAL〕

Development of a novel training model for dental infiltration anesthetic injections

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Abstract

A new dental training model (M2004IA) for infiltration local anesthetic injection was developed. In this new training model silicon gingival mucosa was designed to expand upon insertion of a needle, this to be followed by introduction of a local anesthetic solution into the silicon gum and silicon gingival mucosa (SGM). This study measured the injection pressure during injection under the SGM.

The model M2004IA-HP was designed for hard palate infiltration anesthetic injection training involving the anterior and middle superior alveolar (AMSA) branch of the maxillary nerve. The SGM surrounding the glass filter and the urethane resin jaw (URJ) are held together with glue to maintain space that will permit expansion. The injection pressure for the M 2004IA was 241.3±32.1(mean±SD) mmHg at the end of a 0.5 ml injection.

The lower jaw of the M2004IA (M2004IA-LMBG) was designed for infiltration anesthetic injection training involving the first molar buccal gingiva. The injection pressure for delivery of 0.5ml of solution over approximately 90 seconds was 357.2 ±15.0 mmHg at the end of the injection. The pressure following the start of injection with the M2004IA-LMBG was 5.3± 2.3 mmHg one second after the start of injection, and 109.2±12.0 mmHg at 10 seconds. These values approximated the actual injection pressures from previously reported (Kudo et al., 2004). Infiltration anesthetic injections ; therefore, this novel device, the M2004IA, is effective to generate injection pressures similar to those actually experienced by human volunteers. The model is also suitable for low-pressure injection training. Training in pain-free local anesthetic injection, e. g., low-pressure injection, is essential to promote safe dental treatment under local anesthesia. The newly developed M2004IA enables the simulation of authentic infiltration anesthetic injection conditions. An intensive effort to provide safe training, and also with respect to continuing pre-clinical training in infiltration anesthetic injection with the introduction of the M2004IA can be anticipated.

Key words : Pre-clinical training model, Infiltration anesthetic injections, Local anesthetic injection, Dental students education, Promotion of dental safety

Introduction

The infiltration anesthetic injection model was developed for dental training in local anesthetic injection of solution (M2004 IA ; Fig.1). The silicon gingival mucosa in this model was designed to expand upon insertion of the needle and the introduction of local anesthetic solution into the silicon gum and silicon gingival mucosa (SGM). In addition, the injection pressure was measured during injection under the SGM. The primary characteristics and details of the performance of this novel model are presented in this report.

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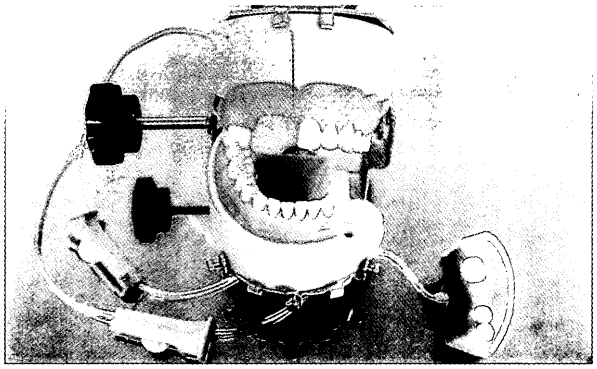

Fig.1 Complete view of Model-2004IA

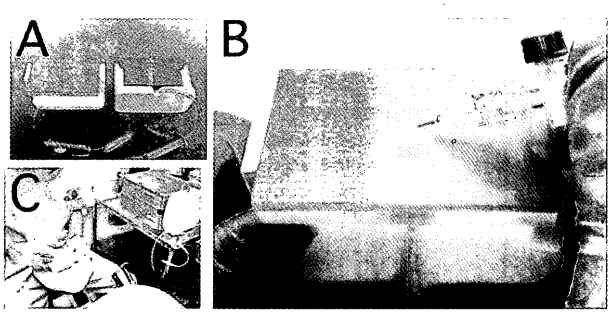

Fig.2 Local anesthetic injection training for 5th year dental students with electrical injection syringe and oral mucosa model (Model-2003IA)
A : Complete view of M2003IA (left ; Top view, right ; Bottom view)
B : Bulge formation at 0.5ml injection
C : Use the M2003IA for pre-clinical local anesthetic injection training in 5th year dental students with electric injection syringe

Methods

1. Development of bulge formation model for injection

The experimental model, which was designed to permit SGM expansion upon injection of 0.5ml of solution (M2003IA ; infiltration anesthesia model), was developed in 2002 and the model was employed in pre-clinical training in 2004. The silicon mucosa in M2003IA has a urethane resin jaw (URJ) equipped with an embedded glass filter (#100-120μm ; diameter, 18 mm ; thickness, 3mm) for solution penetration. A plastic tube is connected to the glass filter to facilitate solution drainage, and tube endings outside of the apparatus are clamped (Fig.2-A). The device was manufactured by Nissin Dental Products, Inc.. The bulge formation at 0.5ml solution injection is presented in Figure 2-B. Injection pressures for delivery of a 0.5ml solution over approximately 90 seconds (Hochman et al., 1997) was 157.3±4.1 mmHg at the end of the injection. In this study, an infiltration anesthetic injection model (M2004IA) of the hard palate and the lower molar buccal gingival were developed for the bulge formation model (M2003IA) improving the silicon mucosa.

2. Measurement of injection pressure with M2004IA

The local anesthetic, 2% lidocaine hydrochloride with 0.0000125% epinephrine (supplied in a dental local anesthetic cartridge) was used. The syringe was an electric-type syringe, The Wand™, and the needle was a special disposable needle for this electric device (30G x 1/2", outer diameter 0.30 mm, and length 12 mm). The injection speed of the device can be adjusted to two levels : fast (30 sec/ml) or slow (160 sec/ml) (Hochman et al., 1997). The injection pressures with the slow injection speed were measured in this study.

For the connections between the pressure transducer and the injection apparatus, the methods of Rood (Rood, 1978) and Pashley (Pashley et al., 1981) were modified as follows. A pressure transducer (TP300T ; NIHON KOHDEN Co., Ltd.) was connected between the hub of the needle and the syringe, and injection pressure was measured continuously in real time from immediately before puncture till removal of the needle, using an invasive sphygmomanometer (AP-641G ; NIHON KOHDEN, Co., Ltd.) and analytical software (gmview Ⅱ-CORE ; GMS Co., Ltd.). The sphygmomanometer could measure a maximum 2,000 mmHg.

Results

1. Novel infiltration anesthesia injection model of the hard palate

1) Development of the infiltration anesthesia injection model of the hard palate (M2004IA-HP)

The novel infiltration anesthesia injection model (M2004IA-HP) in 2004 was developed by the authors, and the M2004IA-HP was designed for palatum durum infiltration anesthetic injection training involving the anterior and middle superior alveolar (AMSA) branch of the maxillary nerve. The teeth from left upper premolar to the central incisors were considered to be absent, and a glass filter (diameter 7mm) was positioned in the middle of the free gingival border and epistome midline com-

pound suture at the bisector of the premolar. The SGM thickness was 2mm, and the SGM surrounding the glass filter and the URJ were held together with glue to maintain a space to permit expansion. The bulge formation at the time of the 0.5ml solution injection is presented in Figure 3.

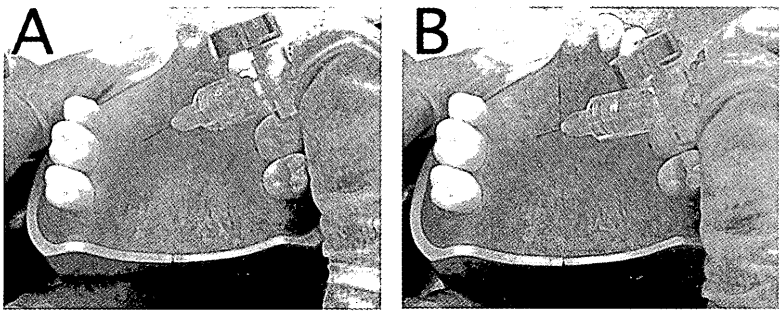

Fig.3 Bulge formation after 0.5ml solution injection with hard palate model (Model-2004IA-HP)
A : At the start of injection
B : At the end of the 0.5ml injection

2) Injection pressures of M2004IA-HP

The injection pressures for delivery of 0.5ml of solution over approximately 90 seconds were 5.3±2.3 (mean±SD, n=3) mmHg one second after the start of injection, 21.3±12.2 mmHg at 3 seconds, 61.3±18.5 mmHg at 10 seconds, 145.3±32.6 mmHg at 30 seconds, 252.0±4.0 mmHg at 60 seconds, and 241.3±32.1 mmHg at the end of the 0.5ml injection(Fig.5).

2. Novel infiltration anesthesia injection model for the lower molar buccal gingival

1) Development of infiltration anesthesia injection model of the lower molar buccal gingival (M2004IA-LMBG)

The lower jaw of the M2004IA-LMBG was designed for infiltration anesthetic injection training involving the first molar buccal gingiva. The lower first molar was considered to be absent, and a glass filter (diameter 7mm) was positioned in the gingivobuccal fold. The SGM thickness was 2mm. The SGM and URJ were not glued within a 15mm radius of the glass filter. The bulge formation after 0.5ml solution injection is presented in Figure 4.

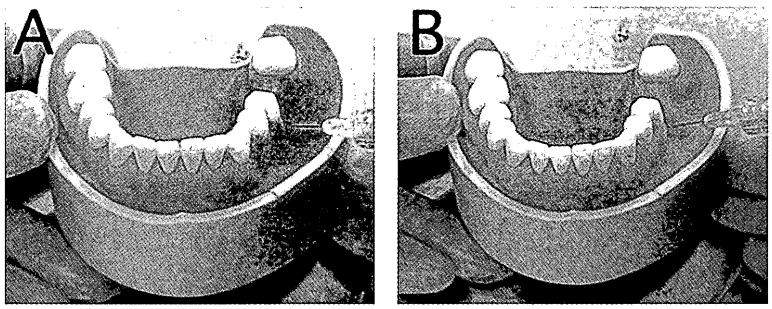

Fig.4 Bulge formation after 0.5ml solution injection with lower molar buccal gingival model (Model-2004IA-LMBG)
A : At the start of injection
B : At the end of the 0.5ml injection

2) Injection pressures of the M2004IA-LMBG

Injection pressures for delivery of 0.5ml of solution over approximately 90 seconds were 5.3±2.3 mmHg (mean±SD, n=3) one second after the start of injection, 29.3±4.6 mmHg at 3 seconds, 109.2±12.0 mmHg at 10 seconds, 223.9±18.2 mmHg at 30 seconds, 295.9±20.7 mmHg at 60 seconds, and 357.2±15.0 mmHg at the end of the 0.5ml injection (Fig. 5).

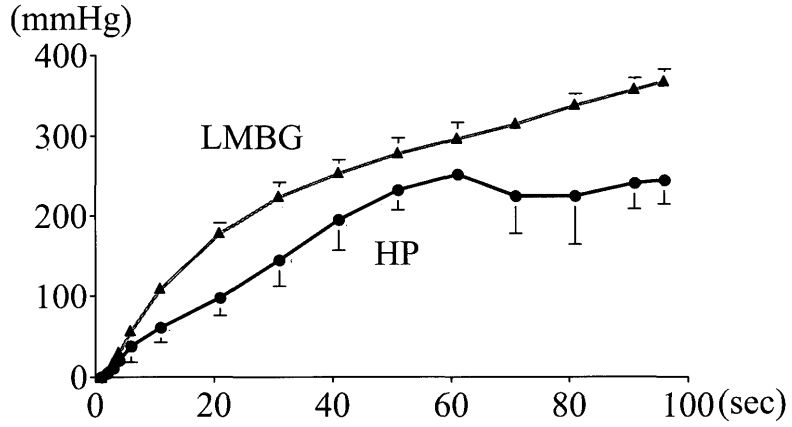

Fig.5 Results of injection pressures with the injection speed 0.5ml/90seconds for Model-2004IA-HP (n=3) and Model-2004IA-LMBG (n=3)

Discussion

The M2004IA, the newly developed infiltration anesthetic injection training apparatus, enabled the injection of solution into SGM. The M2004IA allows practice in low-pressure injection (approximately 250-350 mmHg) of 0.5ml of solution over 90 seconds. Injection conditions for conventional dental local anesthetics in pharmaceutical references state only that it is necessary to "inject very slowly with low pressure", and there are no specific guidelines for the proper speed and pressure of an injection. A previous investigation (Kudo et al., 2004), which employed 0.5ml of local anesthetic (0.0000125% epinephrine) delivered via a 30G needle under the mucosa, produced pressures of 250 mmHg three seconds after the start of the injection reaching 550 mmHg at the end of injection. At the point of the initial injection, a pressure < 300 mmHg appears to be effective in terms of the absence of pain generation ; moreover, pressures < 345 mmHg do not create anxiety in human volunteers, and pressures < 325 mmHg do not cause discomfort (Kudo et al., 2004).

The pressures recorded following the start of injection with M2004IA-HP were 5.3 mmHg at one second, 21.3 mmHg at three seconds, and 241.3mmHg at 0.5ml, and with M2004IA-LMBG they were 5.3 mmHg at one second, 29.3 mmHg at three seconds, and 357.2mmHg at 0.5ml. These values approximate the actual injection pressures in previously reported (Kudo et al., 2004) infiltration anesthetic injections suggesting that this novel device, M2004IA, is effective in generating injection pressures similar to those actually experienced by patients. This model is further suitable for low-pressure injection training although leakage was observed from a hole in the SGM due to a puncture and from the joint between the glass filter and URJ during injection.

From 1981 to 1986, a 5-year dental school pre-clinical training program in dental anesthesiology was performed involving localized anesthetic injections in the clinical training with respect to infiltration and periodontal anesthesia by trainees mutually performing injections in the lower front teeth and conducting anesthesia for the foramen mandibulae as well as in the infraorbital foramen by mutual training. However, Shimada et al documented incidental symptoms such as neurogenic shock and vasovagal syncope during such training (Shimada et al., 2005). Conducting anesthesic injections in the infraorbital foramen was discontinued in 1987 because of such incidents during injection training (Kudo et al., 2002).

The previous conduction anesthesia / needle injection model [M1993CA (Kudo et al., 2002) : developed in 1993, manufactured by Nissin Dental Products, Inc.] was introduced into clinical training in 1994, and the M1993CA was incorporated into a Pre-clinical training system (PCTS) for clinical injection training. Upon injection, the needle tip contacts electrodes in the device causing a lamp to light up and a buzzer to beep. The electrodes were arranged in the URJ and coated with SMG. In the upper jaw, the electrodes were positioned in the infraorbital foramen, incisive foramen and greater palatine foramen in the maxilla. In the lower jaw, the electrodes were positioned 5 mm above the foramen mandibulae and in the foramen mentale.

In pre-clinical training, the model was primarily utilized for needle insertion training for inferior alveolar nerve conduction

anesthetic injection in the foramen mandibulae. The most significant issue regarding the M1993CA corresponded to rupture of the SGM in the anterior ramus mandibulae following approximately 30 needle injections. In 1998, an improved model, M 1998CA, was developed, it was characterized by the utility of a removable silicon mucosa in the anterior ramus mandibulae. Further, the silicon mucosa simulated the anatomical structure in conjunction with adjusted electrode placement. Electrodes were placed in the neck of the mandible of the URJ to enable Gow-Gate method training. The M1998CA posed several challenges : rusting of electrodes due to water- mediated electric currents, SGM rupture at the site of the needle insertion and undesirable lifting of SGM at the anterior ramus of the mandible. Presently, we are in the process of developing a further improved model. This new model, M2005CA, will offer improved durability of SGM ; and additionally, SGM lifting will be eliminated.

Since 2001, clinical training in infiltration anesthesia and periodontal anesthesia of the lower anterior teeth and inferior alveolar nerve conduction anesthesia has been conducted exclusively with an injection training model. With full implementation of Objective Structured Clinical Examination (OSCE) scheduled for 2006, practical training in infiltration anesthetic injection is a necessity for 4th-year dental students. It is impossible to simulate actual patient sensation in reaction to injection with the models. However, dentists must recognize patient emotions, these involve a fear of injection needles, fear of pain, and fear of post-injection discomfort. Further, the medical staff involved, including dental hygienists, must exercise caution when handling syringes and needles in the presence of needle and injection phobic patients (Kudo et al., 2001). Shiny metal syringes, glass-type syringes, pistol-shaped syringes, and large syringes should be kept concealed from dental phobic patients (Kudo et al., 2001), children, and mentally disabled persons (Kudo et al., 2002). We have previously documented cases where patient anxiety intensified pain (Kudo et al., 2002 ; Ohke et al., 2002).

Most fatal medical accidents in the dental field occur during treatment following local anesthetic injection (Kaku et al., 2001). Uncertain ties in the administration of local anesthesia increases this kind of risk during dental treatment, and the addition of a vasoconstrictor to local anesthetics is necessary. The Japanese Society of Hypertension notes that reliable local anesthetic injections are more desirable for dental patients with hypertension than prohibiting the use of localized anesthetic injections consisting of epinephrine. The warnings and cautions sections of pharmaceutical reference materials for local anesthetic agent manuals state that "in rare cases patients may develop shock syndrome or poisoning. Before applying anesthetic agents, patient health conditions need to be fully assessed and it is necessary to always be prepared for emergency care and treatments." To prepare for such situations, the application of an AED in the resuscitation procedure during the first 10 minutes of in-office sudden cardiac arrest as well as participation in medication injection workshops is highly desirable.

Pain-free local anesthetic injections, low-pressure injections, and educational training is essential to promote safe dental treatment under local anesthesia. The newly developed M2004IA enables the simulation of authentic infiltration anesthetic injection. Intensive efforts in to ensure safety and with respect to the contents of continuing pre-clinical training in infiltration anesthetic injection may be anticipated with the introduction of the M2004IA. The current goal is to improve the M 2004IA further for low-pressure injections with real-time measurements of the injection pressure. Presently, an improved infiltration anesthetic injection model is in the process of development. The M2004IA will offer improved durability of SGM to prevent leakage of anesthetic solution.

Conclusion

A new dental training model (M2004IA) for infiltration local anesthetic injection of solution was developed. The injection pressure of the M2004IA-HP was 241.3±32.1 mmHg at the end of a 0.5ml injection over approximately 90 seconds. Pressures involved in M2004IA-LMBG injections were 5.3±2.3 mmHg at one second from the start of injection, 29.3±4.6 mmHg at 3 seconds, and 357.2±15.0 mmHg at the end of the 0.5ml injection. The newly developed M2004IA enables the simulation of authentic infiltration anesthetic injections.

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