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Research paper

Development of a compact induction-heated autoclave with a dramatically shortened sterilization cycle in orthodontic clinics

Takashi Kameda DDS, PhD[a,*], *Kazuo Ohkuma DDS, PhD*[b], *Natsuki Sano DDS, PhD*[a], *Nomintsetseg Batbayar DDS*[a], *Yukari Terashima DDS, PhD*[a], *Kazuto Terada DDS, PhD*[a]

[a] *Department of Orthodontics, The Nippon Dental University School of Dentistry at Niigata, 1-8 Hamaura-cho, Chuo-ku, Niigata City, Niigata 951-8580, Japan*

[b] *Department of Dental Materials Science, The Nippon Dental University School of Dentistry at Niigata, 1-8 Hamaura-cho, Chuo-ku, Niigata City, Niigata 951-8580, Japan*

ARTICLE INFO

Article history:
Received 9 July 2013
Received in revised form
10 March 2014
Accepted 20 March 2014
Available online 18 April 2014

Keywords:
Induction heating
Autoclave
Sterilization
Compact
Short sterilization time

ABSTRACT

Purpose: This article reviews the development of a compact autoclave with a dramatically shortened running time that did not compromise the quality of its sterilization properties including orthodontic appliances, orthodontic mini-implants (anchor screws), instruments and other dental items.

Materials and methods: Induction heating (IH) mechanisms were employed to produce a more compact machine and shorten sterilization sufficiently so that it could be used at chair-side. Intravessel pressure was estimated by a pressure gauge mounted in the lid of the sterilization vessel. A digital multimeter with a K thermocouple set in the lid of the vessel was used to monitor this intravessel temperature.

The level of sterilization achieved with a conventional autoclave and an IH autoclave was quantified by the biological indicator containing vials of Geobacillus stearothermophilus bacteria in growth media.

Results: We found that the minimum effective sterilizing time after reaching the operating pressure was 25, 15, 12.5, 10 and 5 min at 0.20, 0.25, 0.30, 0.35 and 0.50 MPa with a compact IH mechanism, respectively. Combining the values with (i) the time taken to achieve the operating pressure and (ii) ~2–3 min for cooling and removal of sterilized items gave the total sterilization cycle time, which were, on average, 30, 22, 19, 18 and 13 min at 0.20, 0.25, 0.30, 0.35 and 0.50 MPa, respectively.

Conclusions: IH mechanism is useful for compact and speedy autoclave, which reduce total sterilisation time by 40–80% compared with conventional autoclaves.

* *Corresponding author*. Tel.: +81 25 267 1500x303; fax: +81 25 267 1622.
E-mail address: tkameda@ngt.ndu.ac.jp (T. Kameda).

http://dx.doi.org/10.1016/j.odw.2014.03.001

1. Introduction

Autoclaves, which kill pathogens with pressurized steam, are widely used for sterilization in medical environments, especially when the extensive presence of blood/bodily fluids and a high risk of infection demand higher levels of sterilization than achievable by techniques employing heat, unpressurized steam, chemicals or gas [1]. Full-size autoclaves offering this high level of sterilization are generally very large due to large sizes of their complicated mechanical parts [1], and are powered by an electrical mantle heater, which prolongs the running cycle because of the time taken to elevate the intravessel temperature to the required level. These machines are thus not suitable for restricted spaces including chair-side in the dental clinics. Streamlining the autoclave procedure without compromising its effectiveness would be an important improvement that would allow more time to be spent on treating patients not only in dental clinics but also in case of emergencies.

The standard conditions for autoclave sterilization are 121 °C at 0.20 MPa for 20 min or 134 °C at 0.30 MPa for 5 min [1,2]. However, because conventional autoclaves take a considerable time to heat/pressurize and cool/depressurize, the total running time of these machines is ~50–60 min from starting the cycle to removal of the sterilized items. A novel approach would be required to reduce the total sterilizing time and the machine size simultaneously, and we believe that an induction heating system may represent one such novel solution.

In this study, we have developed an induction heating autoclave mechanism that reduces machine size and total sterilizing time such that these procedures can be performed at chair-side in the dental clinic for sterilization of orthodontic appliances, orthodontic mini-implants (anchor screws), instruments and other dental items in front of the patients.

2. Materials and methods

2.1. *Materials*

The sterilizing vessel used for this experiment was milled from a stainless block, and was ~25 cm in diameter and 30 cm in height. The mechanism by which this vessel was heated was electromagnetically produced induction heating (IH) rather than the more conventional mantle heating system. The induction heating system was derived from a commercial IH cooking plate and modified for use in our autoclave (Figs. 1 and 2). The lid of the sterilizing vessel was modified for installation of pressure gauges, thermocouples and valves, including in-line relief valves (Fig. 1).

2.2. *Measurement of pressure and temperature*

Schedules of sterilization by autoclaves are shown in Fig. 3. During these schedules, intravessel pressure was estimated by a pressure gauge mounted in the lid of the sterilization vessel. In Japan, pressure vessels on the market should be under the control of Japanese law, the industrial safety and health law (law No. 57, 1972) and the entire construction code for pressure vessels (notification no. 66 of the ministry of labor, 1989), because of the required safety of devices with pressure vessels. This standardization is decided by the mathematical product of pressure (MPa) and volume (m^3) so that there is a capacitation for pressure vessel. Within the same standard of pressure vessel, pressure vessels with larger volume should be ones with lower pressure. In this study, we targeted the compact autoclave which could be placed near the chair-side, so we tested experimental conditions with higher pressure compared to those of conventional ones, e.g. 0.35 MPa and 0.5 MPa. A digital multimeter (KU-2608, Kaise Inc., Nagano, Japan) with a K thermocouple set in the lid of the vessel was used to monitor this intravessel temperature and report it via

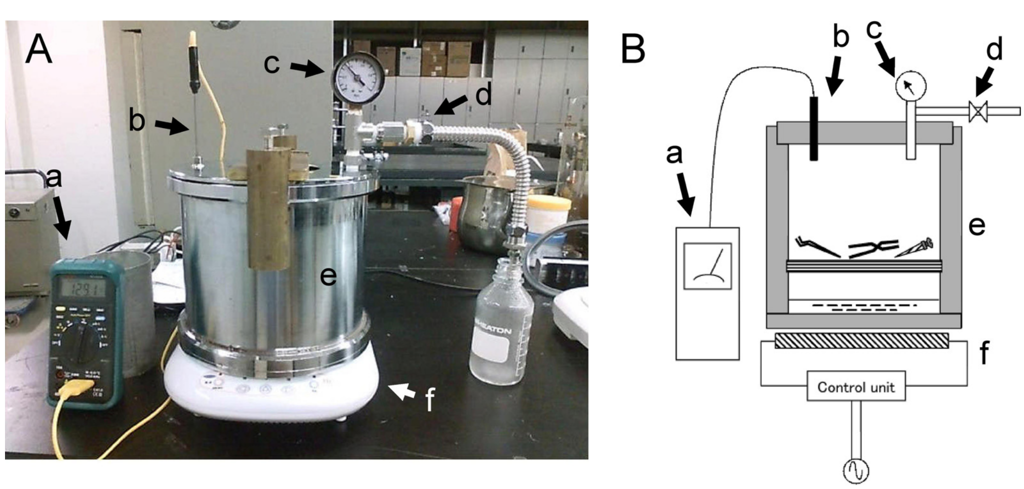

Fig. 1 – Experimental autoclave device created using a modified commercial IH cooking heater. (A) Photograph of an IH autoclave. (B) Schematic representation of an IH autoclave. Alphabet a–f in A and B indicated a digital multimeter (a), a K thermocouple (b), a pressure gauge (c), a relief valve (d), a sterilization vessel (e), and modified IH cooking heater (f), respectively.