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ORIGINAL RESEARCH

Effect of dental chair stabilization method on manual chest compressions

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Abstract

Background: Due to the structural design of dental chairs, they are easily swayed by strong external forces such as manual chest compressions (MCC). When a patient suffers cardiopulmonary arrest during dental treatment, MCC on a dental chair is inefficient. However, under the special circumstances of the dental office, MCC on the dental chair should be preferred if necessary. However, they should be initiated in the special circumstances of dental clinics when necessary. We previously demonstrated the usefulness of a support stool for stabilizing a dental chair during MCC. In this study, we evaluated how this method of using a stool to support a dental chair affects the efficiency of MCC for patients experiencing cardiac arrest while seated in a dental chair. **Methods**: Thirty-two Basic Life Support (BLS)-certified dentists participated in the study. The study was conducted as a randomized crossover trial using Cardiopulmonary resuscitation (CPR) training manikin seated on a dental chair. A stool was placed under the reclined back of the dental chair to stabilize it. MCC was performed for 5 minutes with or without the support stool. We measured eight parameters and fatigue levels in the MCC. **Results**: The findings revealed that the use of a support stool increased the percentage of correct MCC. The "mean MCC depth" was deeper and the fatigue level was reduced. MCC performed with a stool enhanced the accuracy and depth of compressions while decreasing rescuer fatigue. Without the stool, compressions tended to be shallower, less accurate and more physically taxing. **Conclusions**: The use of a support stool significantly improved the quality of MCC performed on a dental chair and reduced rescuer fatigue. When CPR is needed for a patient experiencing cardiac arrest during dental treatment, incorporating a support stool can facilitate effective MCC in the dental setting.

Keywords

Dental chair; Manual chest compression (MCC); Cardiopulmonary resuscitation (CPR); Stool; Fatigue; Manikin

1. Introduction

There are many dental clinics, with approximately 70,000 in Japan and 186,000 in the USA [1, 2]. With the aging of society, many dental patients have underlying health complications. Prevention is an important part of medical safety. However, it is difficult to completely prevent unexpected serious medical accidents. The most critical condition during dental treatment is cardiopulmonary arrest. Previous studies have reported that 0.003 cardiac arrests per dentist per year of practice in French and Belgian [3], 0.2 percent of Brazilian dentists experienced [4] an average of 1 in 500 dentists encountering a case annually in of cardiopulmonary arrest in the United Kingdom over the past 20 years, and up to 10% of dentists in India having encountered cardiopulmonary arrest according to a 2011 study [5, 6]. Despite these statistics, guidelines for primary life-saving procedures in dentistry remain insufficient, with current recommendations based primarily on results from prior studies incorporated into the European Resuscitation Council (ERC) guideline [7, 8]. Most Japanese dentists do not have the skills and experience in intravenous cannulation or advanced airway management, and are not regularly trained in Advanced Cardiovascular Life Support (ACLS), which is essential during cardiac arrest and includes administering drugs such as adrenaline. If a cardiopulmonary arrest occurs, it is crucial to transport as quickly as possible to receive appropriate treatment. In Japan, emergency medical services (EMS) aim to transport patients to hospitals promptly while performing BLS/ACLS. The average EMS response time from call receipt to arrival at the scene is 10.3 minutes nationally and 9.4 minutes in Tokyo (in the metropolitan area) [9]. During this interval, the quality of cardiopulmonary resuscitation (CPR) administered at the dental clinic is critical. According to the American Heart Association (AHA), for every minute delay in the resuscitation of a patient in cardiopulmonary arrest, the patient's chance of survival decreases by 10% [10]. Early, high-quality CPR, rapid defibrillation and appropriate care after cardiac arrest are essential for patient survival [11]. The depth of chest compressions has a significant impact on survival rates [12–14]. It is difficult to use the recommended method of performing chest compressions by moving the patient to a hard floor in common dental clinics. This is due to the small size of clinics in Japan, where many are confined spaces, such as single rooms in rented apartments, with medical instruments fixed to the floor and limited space or manpower [15]. These constraints force rescuers to perform chest compressions directly on the dental chair, potentially compromising the quality of compressions. Additionally, international recommendations advise rotating rescuers every 2 minutes to reduce fatigue during CPR [11]. However, due to limited staff in dental clinics, rescuers may need to continue compressions for prolonged periods. Therefore, it is important to reduce fatigue for each rescuer [16–18]. In the efficiency of chest compressions, depth, rate and recoil rate are especially important. Hands-off time, or time spent not delivering compressions, is also an important facet of CPR quality, particularly in the initial minutes of a witnessed cardiac arrest [11]. Incomplete chest compressions reduce venous return to the heart and decrease mean arterial pressure and coronary and cerebral perfusion pressures. Our previous research focused on methods to reduce the vertical displacement of the dental chair during chest compressions [19–21]. Our method stabilizes the dental chair for chest compressions by placing a stool under the reclining backrest. This method has been recommended in the 2015 and 2021 ERC guidelines [7, 8]. Further studies have shown that the support effect depends on the position of the stool. In many types of dental chairs, displacement was found to be significantly reduced by positioning the stool under the shoulder, rather than directly under the chest pressure area [21]. However, the impact of this method on the quality of chest compressions and rescuer fatigue has not yet been studied. This study aimed to compare the quality of manual chest compressions (MCC) performed with and without a stool, the differences in rescuer fatigue, using a manikin simulating a patient seated on a dental chair.

2. Materials and methods

2.1 Study design

This study employed a crossover experiment design with a single-blind method conducted in a controlled laboratory environment. Well-trained participants performed CPR on a manikin (Laerdal Little Anne® QCPR Manikin; Laerdal Medical, Stavanger, Norway) to investigate the effects with and without the supporting stool to a dental chair on chest compression quality and fatigue levels.

2.2 Participants

This study recruited thirty-two volunteer dentists. They had been certified in formal BLS techniques in the AHA's provider course. All the participants were right-handed. Participants with cardiovascular disease, upper extremity impairments, spine-related disorders and other disorders were excluded from the study, as such conditions were judged unsuitable for participation.

2.3 Equipment

The Laerdal® Little Anne QCPR Manikin equipped with a PC SkillReporter® system (version 2023, Laerdal, Stavanger, Norway) was used for measuring and recording CPR data. The monitoring screen was not visible to the participants and no feedback was given.

2.4 The dental chair and stool

In our previous study, various dental chairs were assessed for displacement during MCC. For this study, we used the dental chair (SIGNO Treffert®; MORITA, Osaka, Japan), which features a modern design with a heavily curved backrest, making it particularly challenging to stabilize with a stool. The study procedure was performed according to a previously established method [21]: the CPR manikin was positioned on the reclined dental chair with the upper end of the manikin torso aligned with the top edge of the backrest. A 15-kg weight plate was added to the weight of the manikin to correct for the torso weight of an adult patient. The stabilizing stool placed under the backrest of the dental chair for this study was round with a hard seating surface (diameter 30 cm; height 45 cm; FB-01ALLBK, Fuji Boeki Co., Ltd. Osaka, Japan). The stool's seat was set to vertically contact the backrest under the manikin's shoulders. This position has reduced the most displacement in our study [21], Fig. 1. A cloth covered the side of the dental chair backrest so that participants could not see whether a stool was in place (With) or not (Without).

2.5 CPR quality measurement

All the participants were required to complete chest compressions quality tests in two situations (with or without a stool under the backrest of the dental chair) in random order. They followed the chest compression technique described in the 2020 AHA Guidelines [11] which includes a compression depth of 50–60 mm, a compression rate of 100–120 times per minute, minimizing interruptions in chest compressions, and allowing complete chest wall recoil. Each session involved 5 minutes of chest compressions on a manikin. Before the test, the participants checked the tempo 120 times on a metronome. The 5-minute duration was intentionally chosen, exceeding the usual 2-minute intervals recommended in the guidelines. This adjustment accounted for the constrained space, limited personnel and specific environmental conditions of a dental clinic. Performing MCC on a dental chair is like performing MCC on a stretcher in an elevator, for example, in a situation where the treatment time per rescuer is longer on purpose [16–18]. At the end of each situation, the participant was asked to assess the level of fatigue using the visual analog scale (VAS). Using a ruler, the score was determined by measuring the distance (mm) on the 100-mm line between the "no fatigue" anchor and the participant's mark, providing a range of scores from 0–100 (%). Participants were required to rest for at least twenty-four hours between the tests, and no additional hard exercise or

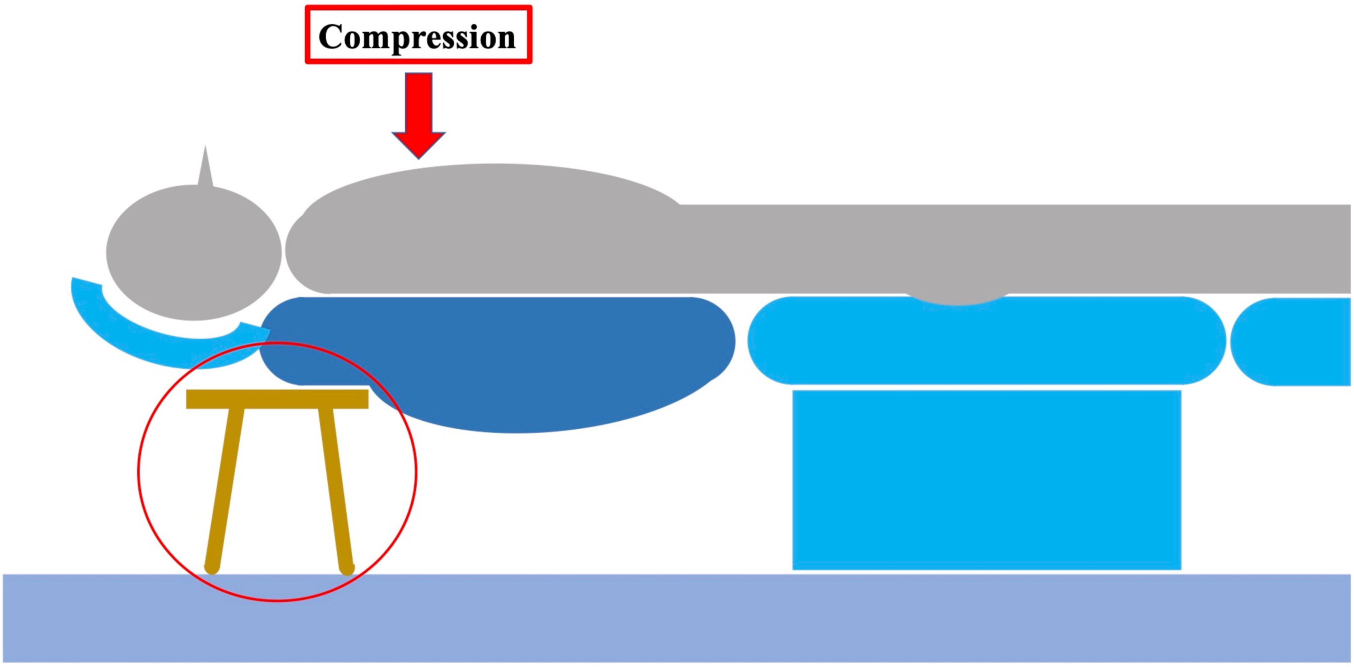

FIGURE 1. The stool position for manual chest compressions. The stool was placed under the shoulders. When the backrest of the dental chair was curved in shape, placing the stool under the shoulder side reduced the vertical displacement.

heavy work was allowed during the rest period to prevent them from muscle fatigue or feeling tired. The primary outcome was the percentage of correct chest compressions relative to the total number of chest compressions (Correct MCC). MCC was regarded as correct when depth, pressure point and pressure release Chest compression rates are suboptimal according to the CPR guidelines [11]. Secondary outcomes were MCC depth (MCC too deep, MCC too shallow, Mean MCC depth), pressure point, pressure release and rate of MCC, and the level of fatigue.

2.6 Data analysis

All participants completed the tests in this study. Data from the Manikin and the VAS scale were exported to Microsoft Excel (Excel version 16.65 in Microsoft 365 for Macintosh, Microsoft Corporation, Redmond, WA, USA) for processing. Data from the manikin were calculated using the SimPad PLUS® device (204-30001, Laerdal, Stavanger, Norway) with activated SkillReporter® software (version 2023, Laerdal, Stavanger, Norway). This study adopted MCC quality parameters of Correct MCC (%), Correct MCC depth (%), MCC too deep (%), MCC too shallow (%), Mean MCC depth (mm), Correct pressure point (%), Correct pressure release (%), Mean MCC rate (min^{-1}) and VAS (%).

2.7 Statistical analysis

The normal distribution of the data was assessed using the Kolmogorov-Smirnov test. Paired-sample comparisons were conducted using the Student's *t*-test for data with a normal distribution and the Wilcoxon test for non-normally distributed data. The significance level was set to $p < 0.001$. These statistical analyses were performed using R® software for Mac OS X Cocoa (version 4.3.2 (31 October 2023); R Development Core Team. R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria). Data are presented as median values with interquartile ranges (IQR). A *post hoc* power calculation for the percentage of correct chest compressions (with *vs.* without a stool) was conducted, yielding a statistical power of 0.90. This statistical analysis was performed with the statistical software G*Power for Mac OS X® (version 3.1.9.6., Faul, Erdfelder, Lang & Buchner, 2020: http://www.gpower.hhu.de/).

3. Results

The study included 32 active dentists (9 women), with a mean age of 29 ± 2 years, mean height of 168 ± 4 cm, and mean weight of 64 ± 12 kg.

3.1 The percentage of correct MCC (%)

The percentage of correct MCC with and without a stool is shown in Table 1 and Fig. 2. When a support stool was used, the percentage of correct MCC was higher compared to when no stool was used (with a stool: 38.5% (IQR 28–49%) *vs.* without: 35.5% (IQR 25–44%); $p < 0.001$).

3.2 The percentage of correct MCC depth (%)

The percentage of correct MCC depth with and without a stool is shown in Table 1 and Fig. 3. Compared to the case without a stool, the percentage of correct MCC depth was higher with a stool (with: 42.5% (IQR 33–60%) *vs.* without: 40.0% (IQR 26–51%); $p < 0.001$).

TABLE 1. Manual chest compressions without or with a support stool on a dental chair.

	Without	With	p Value
Correct MCC (%), Median (Range)	35.5 (25–44)	38.5 (28–49)	<0.001
Correct MCC depth (%), Median (Range)	40.0 (26–51)	42.5 (33–60)	<0.001
MCC too deep (%), Median (Range)	0.0 (0–22)	3.5 (0–31)	<0.001
MCC too shallow (%), Mean (SD)	43 (9)	37 (10)	<0.001
Mean MCC depth (mm), Median (Range)	52 (50–59)	57 (50–60)	<0.001
Correct pressure point (%), Median (Range)	97 (96–99)	98 (97–99)	0.010
Correct pressure release (%), Median (Range)	98.0 (97–99)	98.5 (97–99)	0.012
Mean MCC rate (min^{-1}), Median (Range)	105 (99–127)	111 (100–129)	<0.001
VAS (%), Median (Range)	8.5 (8–10)	7.0 (5–9)	<0.001

MCC: manual chest compressions; VAS: visual analog scale; SD: standard deviation.

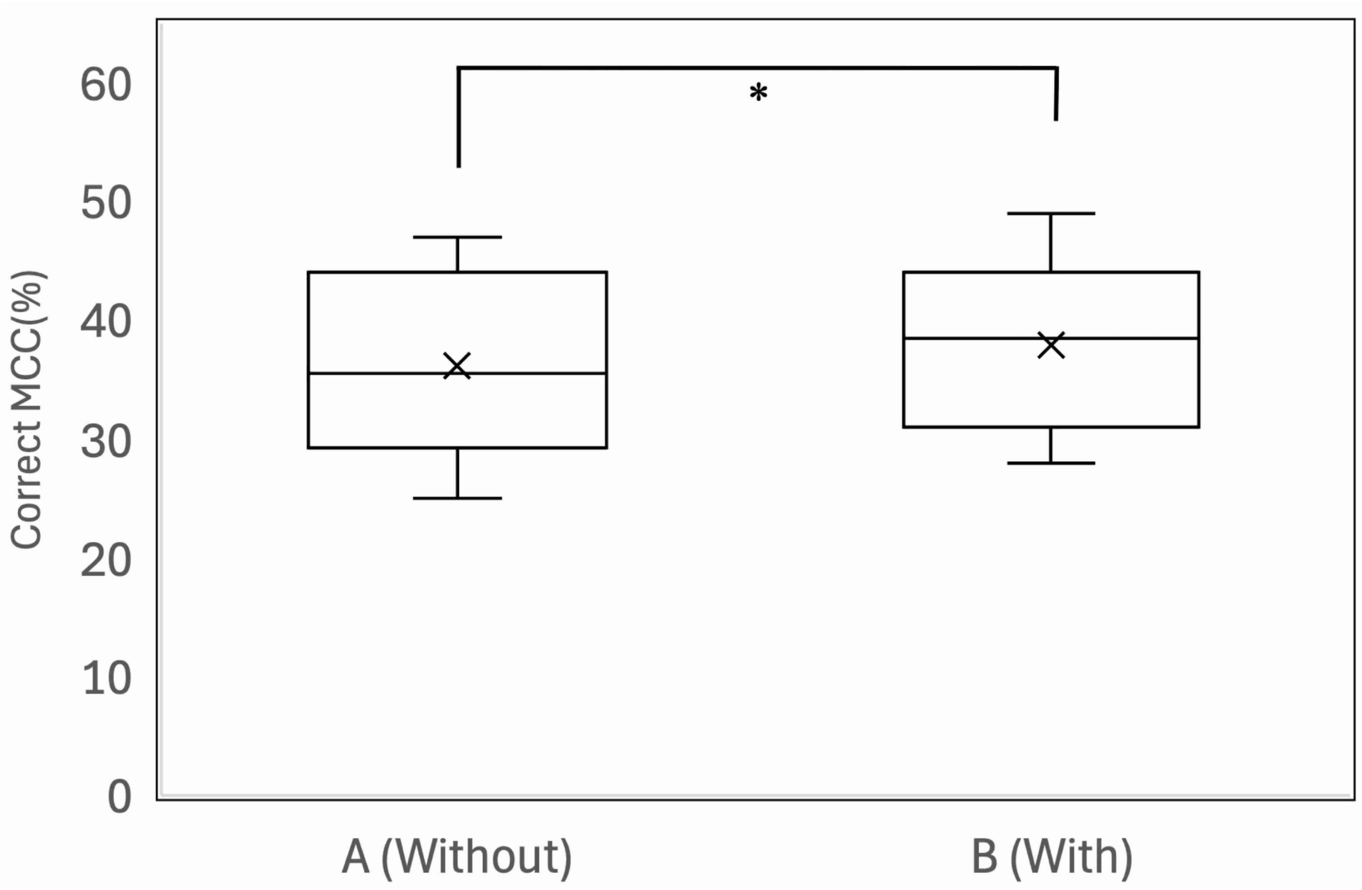

FIGURE 2. Correct MCC (%). Data are given for MCC without (A) and with (B) support stool. *Indicates with a stool were significantly different from those without one, $p < 0.001$. ×: Mean. MCC was considered correct when depth, pressure point and pressure release, as well as chest compression rates, corresponded with CPR guidelines. MCC: manual chest compressions.

3.3 The percentage of MCC too deep (%)

The percentage of MCC too deep with and without a stool is shown in Table 1. Compared to the case without a stool, the percentage of MCC too deep was lower with a stool (with 3.5% (IQR 0–31%) *vs.* without: 0% (IQR 0–22%); $p < 0.001$).

3.4 The percentage of MCC too shallow (%)

The percentage of MCC too shallow with and without a stool is shown in Table 1 and Fig. 4. When the dental chair was unstable, the percentage of MCC that was too shallow was higher. The results showed that the percentage of MCC that was too shallow was reduced with a stool (with 37% (SD 10%) *vs.* without 43% (SD 9%); $p < 0.001$).

3.5 Mean MCC depth (mm)

The mean MCC depth with and without a stool is shown in Table 1 and Fig. 5. Compared to the case without a stool, the mean MCC depth was deeper with a stool (with 57 mm (IQR 50–60 mm) *vs.* without: 52 mm (IQR 50–59 mm); $p < 0.001$).

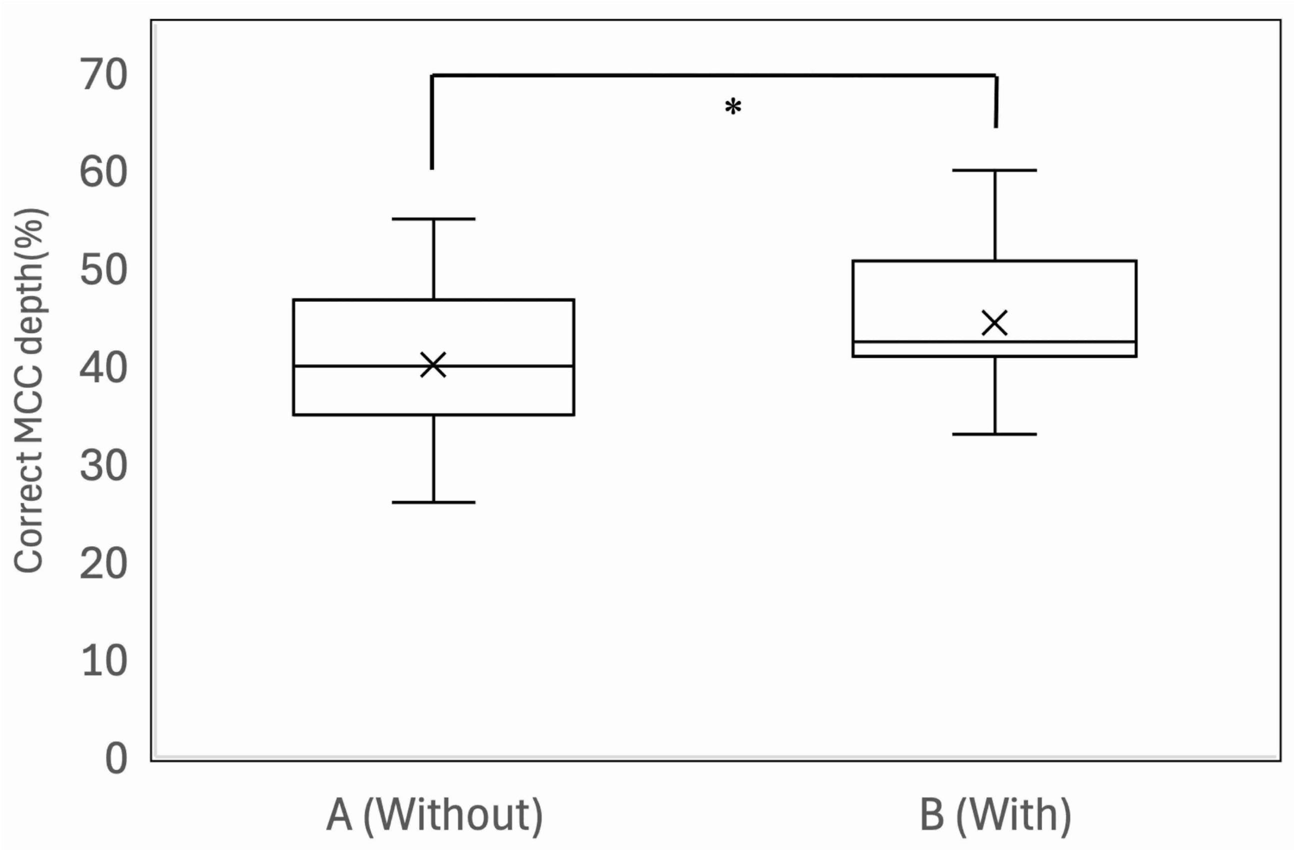

FIGURE 3. Correct MCC depth (%). Data are given for MCC without (A) and with (B) support stool. *Indicates with a stool were significantly different from those without one, $p < 0.001$. ×: Mean; MCC: manual chest compressions.

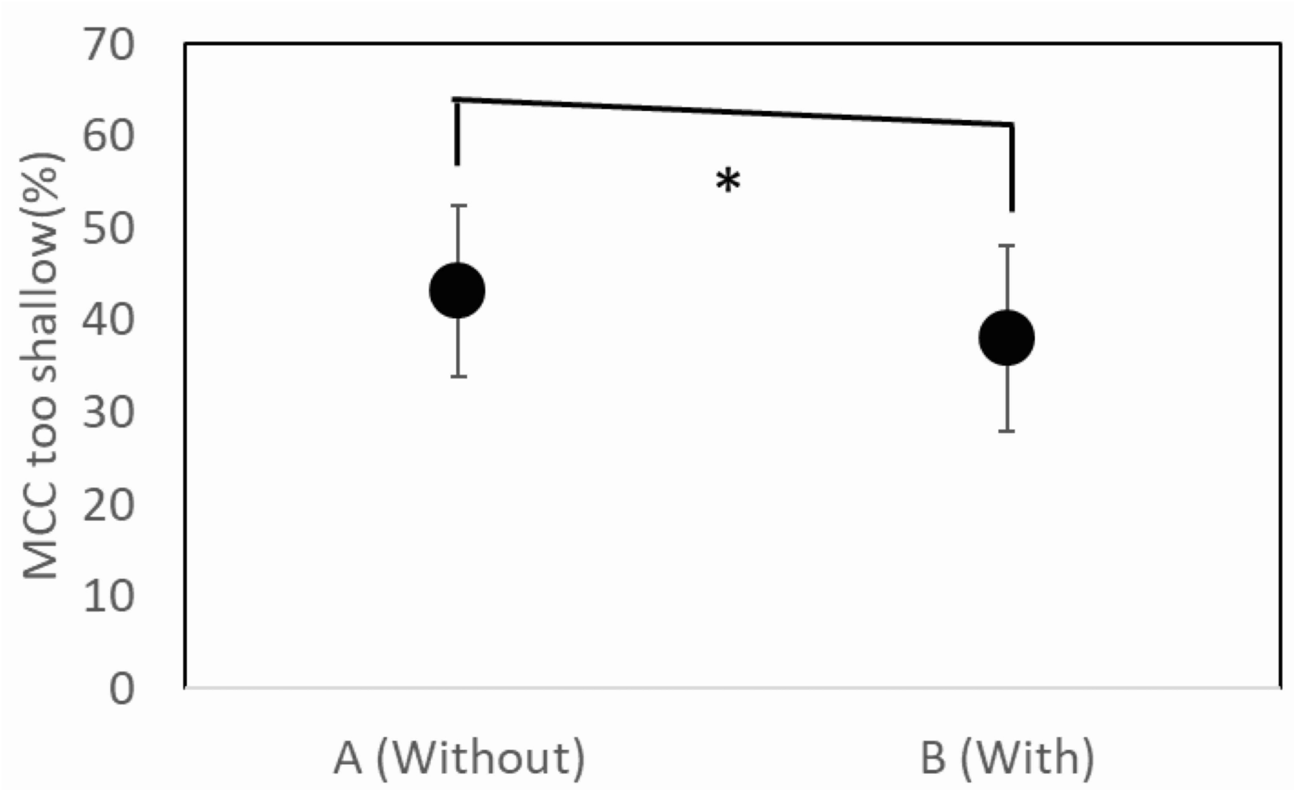

FIGURE 4. MCC is too shallow (%). Data are given for MCC without (A) and with (B) support stool. *Indicates with a stool were significantly different from those without one, $p < 0.001$. MCC: manual chest compressions.

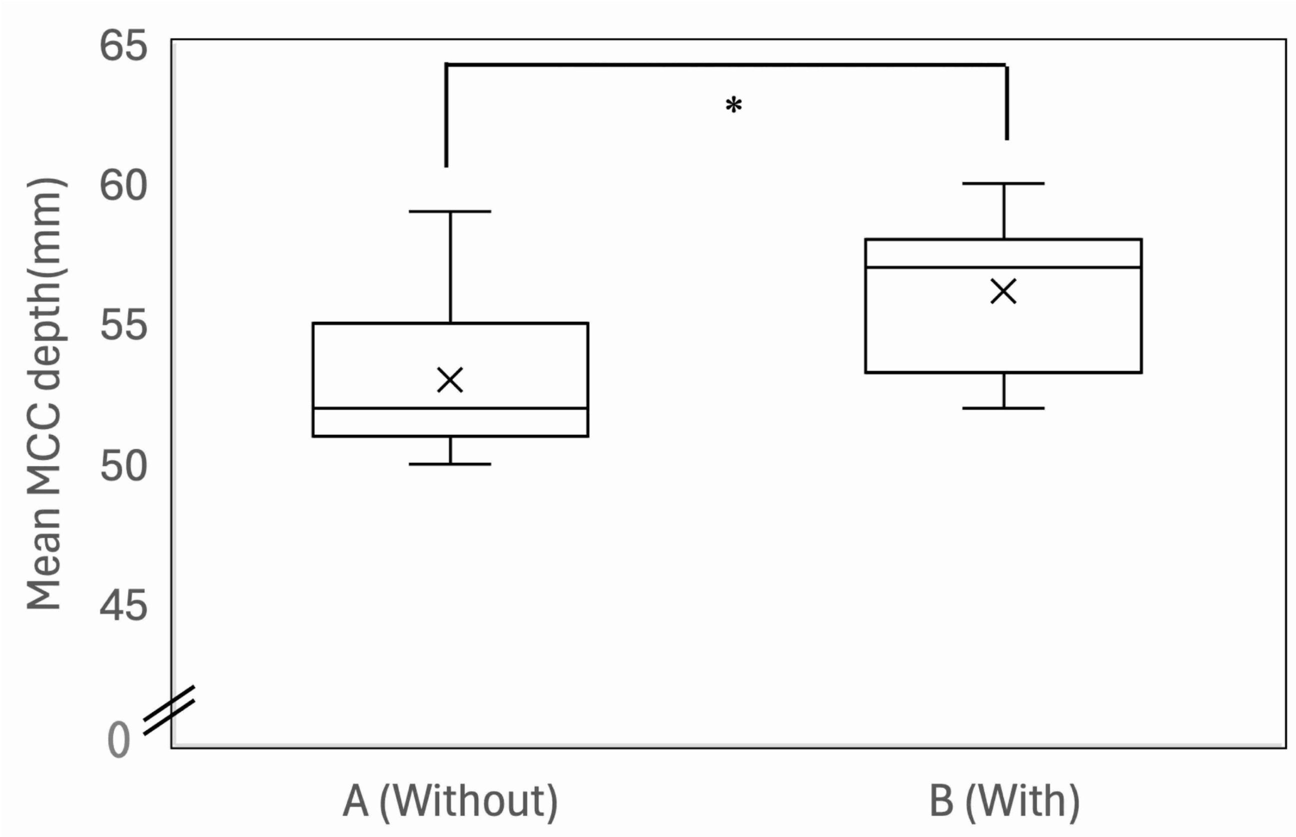

FIGURE 5. Mean MCC depth (mm). Data are given for MCC without (A) and with (B) support stool. *Indicates with a stool were significantly different from those without one, $p < 0.001$. ×: Mean; MCC: manual chest compressions.

3.6 The percentage of correct pressure points (%)

The percentage of correct pressure points with and without a stool is shown in Table 1. Compared to the case without a stool, there were no significant differences in values with a stool (with 98% (IQR 97–99%) *vs.* without 97% (IQR 96–99%); $p = 0.01$).

3.7 The percentage of correct pressure release (%)

The percentage of correct pressure release with and without a stool is shown in Table 1. Compared to the case without a stool, there were no significant differences in values with a stool (with: 98.5% (IQR 97–99%) *vs.* without 97% (IQR 97–99%); $p = 0.012$).

3.8 Mean MCC rate (min^{-1})

The mean MCC rate with and without a stool is shown in Table 1. Compared to the case without a stool, the mean MCC rate was higher with a stool (with 111 min^{-1} (IQR 100–129 min^{-1}) *vs.* without 105 min^{-1} (IQR 99–127 min^{-1}); $p < 0.001$).

3.9 The level of fatigue using visual analog scale (VAS) (%)

The level of fatigue (VAS) with and without a stool is shown in Table 1. Compared to the case without a stool, the level of fatigue was lower with a stool (with 7% (IQR 5–9%) *vs.* without: 8.5% (IQR 8–10%); $p < 0.001$).

4. Discussion

During dental treatment, severe complications including cardiac arrest can occur due to factors such as the use of adrenaline-added local anesthesia, aspiration of dental materials, asphyxiation and psychological stresses [22]. More than 80% of medical accidents with dental patients occur seated on a dental chair [23]. CPR in dental clinics can be compared to the situation in general hospitals, where studies report that 67% of patients receive CPR on a mattress without being moved from the bed [24–26]. However, in smaller, more crowded dental clinics, chest compressions are typically performed directly on the dental chair. Unfortunately, dental chairs are not ideal for CPR due to their instability under the external forces of chest compression. The effectiveness of using a backboard for chest compressions on beds and stretchers has been reported in previous studies [24–26]. However, the main problem with performing chest compressions on a dental chair is the swaying motion of the entire chair. If the dental chair can be stabilized to withstand the pressure of chest compressions, appropriate CPR can be started quickly on the dental chair without moving the patient to the floor. This is particularly important in Japan, where it takes an average of eight minutes or more for an ambulance to arrive at a scene, due to factors such as distance, limited emergency facilities and traffic congestion. Furthermore, the limited and tight space around the dental chair, and there are often few staff members available to perform MCC on a patient on a dental chair, like the situation of performing MCC on a stretcher in an elevator [27–29].

In this study, participants performed chest compressions for five minutes, which is much longer than the two minutes typically recommended by CPR guidelines. Rescuer fatigue is known to affect the quality of chest compressions [14, 26, 29, 30]. After initiation of chest compressions, the depth of chest compressions decreases with time due to rescuer fatigue. As the depth of chest compressions decreases, coronary perfusion pressure decreases, resulting in a decreased likelihood of restoring spontaneous circulation [14, 31, 32]. Additionally, fatigue negatively affects the depth of chest compressions and other important parameters that are indicators of CPR quality. Higher chest compression rates were significantly correlated with the initial return of spontaneous circulation. Previous studies have suggested that a faster chest compression rate is related to fatigue [13]. However, faster chest compression rates can worsen chest rebound and compression depth scores and lead to an earlier onset of fatigue [33]. In this study, participants performed MCC at what they felt was the correct tempo without the use of a metronome. When a support stool was used, the IQR showed that more compressions were performed at rates greater than 120 min^{-1}, which is considered too fast. The present results suggest that the stool's support of the dental chair reduced the physical burden on the participant, allowing for a more efficient and deeper MCC. This also suggested that a solo person could maintain an adequate MCC for up to five minutes, which would improve consistency (Table 1). Despite these improvements, the efficiency of MCC with the stool was still less than 40. However, this low efficiency is comparable to that of chest compressions on bed mattresses, which are performed in medical hospitals for more than 60% of patients with in-hospital cardiopulmonary arrest. While there are no clear standards for lifesaving methods in dentistry, this approach shows promise in dental clinics, where CPR conditions are more challenging.

This study demonstrated that using a stool to stabilize the dental chair increases the effectiveness of MCC in a manikin simulating a dental patient. This method is particularly useful when it is difficult to move a cardiac arrest patient from a dental chair to a hard floor and start chest compressions within the recommended 30 seconds.

5. Limitations

This study has several limitations. First, the results were obtained using a manikin, which may not fully reflect real-life conditions, thus limiting the applicability of these findings in actual clinical scenarios. Second, this study was conducted using only one type of dental chair, so the effects of different types of chairs were not considered. Third, previous studies have shown that the height at which the rescuer performs chest compressions significantly impacts CPR efficiency and rescuer fatigue. In the present study, the axillary line height of the manikin uniformly placed on the dental chair was approximately 55 cm, which did not correspond to the appropriate position of each participant and may have affected efficiency and fatigue. Additionally, factors such as the rescuer's body mechanics and posture may have influenced the results. Lastly, participants' physical fatigue was assessed using only a subjective VAS scale rather than objective measures such as electrocardiogram, electromyogram or oxygen saturation. Future research should address these limitations to further evaluate effective CPR techniques in dental settings.

6. Conclusions

The use of a support stool positioned under the shoulders during chest compressions on a patient in a dental chair enhances the quality of chest compressions and reduces rescuer fatigue. This method is expected to improve the overall quality of CPR in the special environment of the dental clinic.

ABBREVIATIONS

CPR, cardiopulmonary resuscitation; MCC, manual chest compressions; AHA, American Heart Association; ERC, European Resuscitation Council; VAS, visual analog scale; BLS, Basic Life Support; ACLS, Advanced Cardiovascular Life Support; EMS, emergency medical services; IQR, interquartile ranges; SD, standard deviation.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

TH, TY—designed the research study. TH, KH—performed the research. TH, TT—analyzed the data. TH, KH and TT—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All procedures in the studies were performed using a manikin model. This article does not involve any research with human participants performed by any of the authors. We consulted the Institutional Review Board (IRB) at Kyushu University, which confirmed that no formal written waiver for ethics approval was required, because of the design of the study. In addition, there was no written consent needed from all healthcare providers.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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