Wydawnictwo UR 2022
ISSN 2544-1361 (online)
doi: 10.15584/ejcem.2022.3.4

http://www.ejcem.ur.edu.pl
European Journal of Clinical and Experimental Medicine
Eur J Clin Exp Med 2022; 20 (3): 272–283

REVIEW PAPER

Comparison of conventional syringe anesthesia and three computer-aided anesthesia systems (Quicksleeper, SleeperOne, and The Wand)

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ABSTRACT

Introduction and aim. The purpose of this study was to compare different Computerized-Controlled Local Anesthetic Delivery (CCLAD) systems to one another in addition to the conventional syringe.

Material and method. The CCLAD systems chosen for this study are the Quicksleeper, SleeperOne, and The Wand. These are discussed in categorical objectives, including the following: duration of anesthesia, analgesic effect, locality; anxiolytic effect; advantages and disadvantages; comfort and safety of use; limitations.

Analysis of the literature. The research found that many factors influence the effectiveness of dental injections, and the CCLAD systems are designed to reduce the ones that cause negative experiences. The injection systems are unique in their descriptions but show many similarities.

Conclusion. The research concluded that each device has its advantages and disadvantages and that its efficiency depends on outlying factors, independent of the injection system used.

Keywords. computerized-controlled local anesthetic delivery, conventional Syringe, local anesthesia, Quicksleeper, SleeperOne, The Wand

Introduction

Anesthesia plays a critical role in dentistry as it can provide a comfortable experience for the patient and allow the operator to perform procedures with ease. Much of the world's population is not keen on visiting the dental office due to previous unpleasant experiences or fear of the „needle". Among the pediatric population, various coping methods are implemented to ease the anxiety levels in children and adults; however, they are not always successful, and as a consequence, treatment is often deferred. Most of the time, their anxiousness is related to the fear of injection and the pain that is felt when the needle penetrates the oral mucosa and diffuses through the injected tissues. The distribution of anesthetics accompanying the conventional syringe technique causes painful swelling of the tissues and their administration at the site of anesthesia. Lack of control over the rate of anesthetic administration increases pain, swelling, and tissue administration, leading to discomfort and unpleasant sensations accompanying local anesthesia. In addition, an uncontrolled and shock increase of pressure in anesthetized tissues may lead to a short-term disturbance of their blood supply and local damage, reducing the effectiveness of anesthesia and increasing the risk of side effects. Some sources of an unpleasant and painful sensation in conventional syringe anesthesia are failure of inferior alveolar nerve block that may require additional attempts, lack of complete anesthe-

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Received: 4.07.2022 / Accepted: 29.07.2022 / Published: 30.09.2022

Singh N, Wyzga S, Yune J, Mathur G, Błochowiak K. *Comparison of conventional syringe anesthesia and three computer-aided anesthesia systems (Quicksleeper, SleeperOne, and The Wand)*. Eur J Clin Exp Med. 2022;20(3):272–283. doi: 10.15584/ejcem.2022.3.4.

sia, and increased pain/anxiety on injection.[1-3] Repeated unpleasant and painful sensations related to the administration of local anesthesia in the past led to the memorized and permanent fear of anesthesia and even the development of dentophobia. The fear of conventional syringe anesthesia can be a reason for many people not to seek dental care or only visit a dentist for emergencies. Moreover, dental professionals often have difficulty performing mandibular blocks, which results in insufficient analgesia and requires a second injection to establish profound numbness leading to the accumulation of unpleasant sensations.[1,2,4,5] This added stress will contribute to the patients' pain and anxiety levels, which can place pressure on the clinician. Additionally, in pediatric patients, the use of conventional syringe anesthesia also poses pain/stress when puncturing the mucosa and can lead to injuries due to self-biting of soft tissues due to numbness.[3,6-8]

Therefore, all anesthetic delivery systems must be explored to determine the best option for our patients and eliminate traumatic experiences. To address the need to alleviate or eliminate the unpleasant effects of conventional syringe local anesthesia and improve its effectiveness, new computerized-controlled local anesthetic delivery (CCLAD) systems have been introduced. Among the well-known and widespread CCLAD systems are Quicksleeper, Sleeper One, and The Wand.

Aim

The aim of this study was to compare conventional syringe anesthesia with Quicksleeper, Sleeper One, and The Wand and discuss their analgesic and anxiolytic effect, the comfort of use, and limitations. It will allow practitioners to determine whether they will use intraosseous injection systems by providing cohesive information regarding the most popular computer-aided anesthesia systems currently used in dentistry. Therefore, our review was designed to answer "Can computer-aided anesthesia systems replace conventional syringe anesthesia?"

Material and methods

The following databases were used to research information regarding content discussed in this paper: Google Scholar, Pubmed, and Western's Online Database. The selected articles were used to summarize information about the selected objectives for the reader to compare the different computer-aided anesthesia systems and the conventional syringe.

Analysis of the literature

Duration of anesthesia, analgesia effect, and recommended type of anesthesia

One of the most desirable features of local anesthesia is to ensure a good and sufficiently long-lasting anesthetic effect that allows treatment or surgery procedure to be carried out. Although the duration of anesthesia depends on the type of anesthetic, the additional content of vasoconstrictor and the local anesthetic technique used, the method of distribution of the anesthetics may modify the final anesthetic effect. One of the most desirable properties of conventional syringe anesthesia is its versatility and the ability to perform all methods of local anesthesia. The duration of anesthesia for the conventional dental syringe is dependent on the type of anesthetic solution used, and the local anesthetic technique performed. In a study by Fernandez et al. directed specifically towards the inferior alveolar nerve block, the duration of lip anesthesia is between 192–411 minutes (3 hours to 6.8 hours) and the duration of pulpal anesthesia is between 127–258 minutes (2 hours and 24 minutes to 4 hours).[9] CCAL provides not so long the duration of anesthesia but on the other hand it is more targeted anesthesia of a specific area. The duration of anesthetic in the Quicksleeper system is between 30-60 minutes, however, various factors contribute to its effectiveness such as the use of vasoconstrictors, amount of anesthetic, and anatomical variations.[4] Beneito-Brotons et al. determined that the duration of anesthesia in soft tissue was 199.3 minutes using the conventional technique, and 1.6 minutes when using the intraosseous injection. This together concludes to a statistically significant difference between conventional syringe anesthesia and intraosseous injection.[2] According to Nieuwenhuizen et al. the injection time of the SleeperOne was averaged at 2.49 minutes.[10] Intraosseous injections specifically show high success rates, with easy administration and fast onset. Its numbing effects last long enough for endodontic treatment and limited treatment of 1–2 posterior teeth in the mandible.[11] When using the SleeperOne for intraosseous injections, the recommended doses are 1.5–1.8 mL of 4% articaine with 1:100,000 epinephrine for adults, and 0.6–0.8 mL of 4% articaine with 1:200,000 epinephrine for children.[11] In the prospective study between single tooth intraligamentary injections versus a conventional nerve block to extract posterior mandibular teeth by Adubae et al. the onset of action was immediate compared to a 10-minute wait time for the latter.[12] As the Single Tooth Anesthesia system allowed for treatment to begin simultaneously following the administration of local anesthesia, the duration of overall treatment was also faster. Furthermore, when the intraligamentary technique is used, the single tooth and its neighboring soft tissues are the only areas anesthetized. The duration of the anesthesia is shorter and the lips, cheek, and tongue are spared of any loss of sensation. In comparison, the conventional inferior alveolar nerve block had a significantly longer duration of action while numbing the surrounding anatomical structures. In addition, the numbness in these anesthe-

tized patients long surpassed the treatment time of the procedure. The onset of anesthesia using the Wand is quite immediate, resulting in a total duration of around 30 minutes. The analgesic effect of conventional syringe anesthesia is dependent on the injection technique used. Techniques commonly used in dentistry and as discussed in the mentioned studies of this paper are soft tissue infiltration, nerve block anesthesia, inferior alveolar nerve block, and anterior middle superior alveolar nerve block being the most studied. Ample knowledge of the selected technique and related intraoral anatomy is critical in increasing the success rate of the anesthetic, and as seen in the study by Thiem et al the success rate can be 100% if performed correctly.[13] In a study done by Cetkovic et al the overall success rate for pulpal anesthesia with the conventional syringe was between 68.4–94.7%.[14] One of the main factors focused on during this study was the importance of the quality of anesthesia being used. This was based on the relationship between the pharmacological profile of the anesthetic solutions and their capabilities of diffusion and penetration into the surrounding anatomical structures.[13] The onset of pulpal anesthesia also depends on the injection technique and solution used. Onset times are reported to be around 6 to 12 minutes.[13,14] Many authors have concluded through their research that the onset of Quicksleeper is immediate and faster than conventional syringe anesthesia. In a study conducted by Jensen et al. all volunteers reported that the effects of the anesthesia through intraosseous injection were instant.[15] Siwawut et al. examined the effects of Quicksleeper versus conventional anesthesia in 20 adult patients and yielded the following results: mean onset time for intraosseous injection was 1 minute and 3.56 minutes for buccal infiltration.[6] Bigby et al. have also confirmed that when the anesthetic solution is deposited into the spongy bone the onset of action is immediate.[16] The jaw and jawbones contain spongy bone that is highly vascularized, which allows for quick metabolism of anesthetic solution and explains why the analgesic effect is lower in Quicksleeper when compared to conventional syringe anesthesia.[15] Ozer et al. used 0.3 mL and 1.5 mL of 4% articaine solution with 1:100,000 adrenaline in the Quicksleeper system and used supraperiosteal and intraosseous injection methods in their study. They concluded that insufficient duration of anesthesia was due to variability in bone density rather than the amount of solution used.[4] The posterior mandibular region also shows a lower success rate of deep anesthesia with the use of Quicksleeper due to high density and low bone porosity.[17] The anatomy of the buccal and lingual cortical bone can also contribute to decreased success rates as the distance is reduced between these plates, which may cause later diffusion of the anesthetic.[18] In contrast, Siwawut et al. used 1.7 mL of 4% articaine with 1:100,000 epinephrine for intraosseous injection and 3.4 mL of 4% articaine with 1:100,000 epinephrine for buccal infiltration for mandibular first molars and obtained the following results of 95% and 80%, respectively.[6] Sovatdy et al. also confirmed the success and effectiveness when inferior alveolar nerve block was administered using Quicksleeper for mandibular third molars.[1] Sixou et al. conducted research among 181 children and adolescents aged 4 to 16, who underwent 215 sessions using intraosseous injections of 4% articaine with 1:200,000 epinephrine using the Quick Sleeper 2 system.[7] The analgesic effect among patients with primary dentition who had endodontically treated teeth, restorations, or needed extractions was 95%, while for permanent teeth with similar clinical presentations was 87.9%. This data suggests that the Quicksleeper is an effective aid that can be used in both dentitions while fulfilling routine dental procedures. Occasionally an inferior alveolar nerve block by intraosseous injection can be unsuccessful in controlling pain, and examples of such cases are molar incisor hypomineralization or severe pulpal inflammation. An inflamed pulp is often difficult to anesthetize and the additional solution is required to sedate the target tooth. Many authors have focused their research on the effectiveness of Quicksleeper in cases of irreversible pulpitis. A few papers have suggested that the success rate is between 82% and 95%, which can become 100% if a supplementary intraosseous injection is applied.[5,7,16-21] Smaïl-Faugeron et al conducted a single-blind, combined split-mouth and parallel-arm randomized controlled trial in the evaluation of Quicksleeper comparing conventional infiltration anesthesia in pediatric patients. They concluded that Quicksleeper had a profound analgesic effect in cases of molar incisor hypomineralization or severe pulpal infection.[22] Additional studies have also claimed a success rate of 71% to 98% in cases of irreversible pulpitis.[2,6,8,22,23] In the study done by Nieuwenhuizen dentists that planned on injecting 0.6mL of analgesia fluid to patients, tend to give more solution because SleeperOne ran quicker than other injection systems.[10] The SleeperOne is eligible for direct injection into cancellous bone in pediatric patients which prolongs anesthesia of the teeth and creates the fast onset of anesthesia.[11] In addition to reduced pain from the controlled delivery speed, the intraosseous injection earned a higher preference from patients 58.9–69.7%.[11] The Wand can perform multiple injection techniques. It can perform intraligamentary single tooth injections that are reported to be less toxic compared to the traditional inferior alveolar nerve block as less solution is needed to achieve the same depth of anesthesia. The Single Tooth Anesthesia system intraligamentary injection technique can provide a quick-acting localized numbness with the ability to regain normal levels of sensation.[12] The periodontal ligament injection can achieve the same efficacy level as

the conventional inferior alveolar nerve block intraosseous injection without having as many adverse effects. Its effects are limited to a single tooth and its surrounding structures, whereas the inferior alveolar nerve block intraosseous injection spans over a larger area, affecting the structures around the zone of treatment and the surrounding cheek and tongue.[24] Multiple studies have evaluated the efficacy of the Single Tooth Anesthesia system The Wand compared to conventional local anesthetic administration and its relation to different types of treatment performed such as restorative, pulpotomy, and extraction. They concluded that the effectiveness of the anesthesia was independent of the procedure being carried out.[25] Another assessed feature of local anesthesia techniques is their extent determined by the type of performed procedure. The locality of the conventional syringe technique depends on the anesthetic injection technique. Although conventional syringe anesthesia enables painless and reliable anesthesia of the tissues of the operating field, for some procedures it is too broad in relation to the real needs. Moreover, conventional intraligamentary anesthesia requires additional equipment. In this aspect, computer systems have an advantage over conventional syringe anesthesia because they enable the performance of all types of local anesthesia depending on the type of procedure performed. Many studies have concluded that with the use of Quicksleeper only the targeted tooth is anesthetized without affecting any accessory structures.[7] This advantageous feature is possible due to the deposition of the anesthetic solution directly into the cancellous bone of the target tooth.[2,7] Therefore, all patients but especially pediatric patients benefit from the use of Quicksleeper as these individuals reported lower incidents of self-biting injuries, which typically occur with the conventional inferior alveolar nerve block method.[3,4,7,23] Sixou et al. reported that only 6.5% of patients in their study experienced lower lip numbness but mildly as they could still feel their lips.[7] Additionally, a study conducted by Ozer et al. reported that Quicksleeper can anesthetize the palatal and lingual surfaces of a tooth with a single needle injection.[4] SleeperOne is eligible for most injection techniques and is designed for the intraseptal injections technique in pediatric patients as it can inject with minimal pressure due to the intercrestal bone being thinner in children and cancellous bone being more sparse.[11] Additionally, the local anesthetic can be injected directly into the cancellous bone adjacent to the tooth to be anesthetized. Similar to the Quicksleeper, this method prevents mucosal numbing and self-biting of soft tissue that would be the result of a traditional infiltration method such as buccal infiltration, or mandibular nerve block.[10] Dentists can also treat bilateral teeth in the same appointment with this technique without having to administer two infra-alveolar nerve blocks, which can be uncomfortable for the patient.[11] Upon the initial injection with the pen tip of the Single Tooth Anesthesia system wand, the anesthetic is deposited into the soft tissue at a very slow and controlled rate. The onset is immediate and localized to the area it is administered when used for intraligamentary local anesthesia (ILA) periodontal ligament single tooth injections. Although the Wand is designed primarily for anesthetizing a single tooth at a time with the ILA technique, its use is not limited to only these injections; infiltration and nerve blocks are also possible with this system.[26] The anesthetic is administered at a very slow and controlled rate that is below the patient pain threshold level. This allows for a painless experience as there is a significant decrease in the feeling of the pain due to its unperceivable injection.[27] Drops of anesthetic are released into the soft tissue and have an immediate onset. In response to pain sensation, a significant mean reduction of 1.09 point in Visual Analogue Scale (VAS) is recognized with the Wand when it was compared to a conventional needle.[26] A conventional needle and syringe used for buccal infiltration take 120 seconds at 0.01 mL/sec, while the Single Tooth Anesthesia The Wand administers the anesthetic at a much slower 'ControFlorate' of 0.005 mL/sec initially. When the computerized system recognizes that the needle is inserted at the correct location, cruise mode is activated and droplets of solution enter a RapidFlo rate of 0.03 mL/sec. Administration of the anesthetic takes a total of 100 seconds with The Wand. Painful injections are the effect of administration that is too rapid or with too much pressure which is not consistent due to the different elasticity of patients' soft tissues. Manual methods don't allow for a consistent parameter to be followed, whereas in computerized systems delivery is perceivable and consistent with indication/feedback that you are in the correct region.[28] Detailed data regarding duration of anesthesia, analgesic effect, and recommended type of anesthesia of conventional syringe anesthesia and its comparison with Quicksleeper, Sleeper One, and The Wand were presented in Table 1.

Anxiolytic effect

A patient's past experience and expectations at the dental office strongly influence anxiety levels, where the administration of local anesthetic is seen to be the most painful part of an uncomplicated visit. Pain and anxiety hold a strong relationship interchangeably. In addition, this fear of the pain-anxiety relationship also influences the patient's confidence in the dental professional.[29] Anxiety-inducement and pain during administration of local anesthesia with conventional syringe is reported to be greater compared to CCLAD systems.[30] In a study by Kuşcu et al., the influence of the physical appearance of dental injectors on children was assessed, and it was concluded that the physical appearance of the conven-

Table 1. The duration of anesthesia, analgesic effect, and locality of conventional syringe anesthesia, Quicksleeper, Sleeper One, and The Wand*

Local anesthetic equipment	Duration of anesthesia	Analgesic effect	Recommended type of local anesthesia
Conventional syringe	127–258 minutes.[9]	Dependent on injection technique	Dependent on injection technique
Quicksleeper	30–60 minutes.[4,8,15]	· Onset is immediate.[3,15,16] · Duration is lower than conventional anesthesia.[4,8,15] · Successful analgesic effect for endodontically treated teeth, extractions and teeth with MIH, irreversible pulpitis or severe pulpal inflammation.[2,6,8,22,23]	· Target tooth is only anesthetized.[3] · Can anesthetize the palatal and lingual surfaces with single needle penetration.[4]
Sleeper One	· Averaged at 2.49 minutes (SD=0.56) · Intraosseous injection have high success rates.[10,11] · Recommended dose: adults: 1.5–1.8mL of 4% articaine with 1:100,000, children: 0.6–0.8mL of 4% articaine with 1:200,000 epinephrine for children.[11]	· Quick onset.[11] · Pain free injection.[36] · Prolonged anesthesia.[11]	Most injection sites, and intraseptal injections technique for pediatric patients.[11]
The Wand	~ 30 min and can be used with immediate effect for all procedure types.[26]	· Immediate onset of action.[26] · Can achieve same depth of anesthesia as other techniques while often using less amounts of solution.[12,43] · Pain Free admin + procedure.[12,24]	Designed to be used to deliver single tooth anesthesia via PDL (intraligamentary) injection technique but can be used to deliver anesthesia of all techniques (infiltration – buccal/palatal/lingual, and blocks).[24,26,35,45]

*MIH – molar incisor hypomineralization, SD – standard deviation, PDL – periodontal ligament

tional syringe is more anxiety-inducing when compared to other CCALD systems.[31] Many authors through their studies have concluded that the Quicksleeper is painless or may produce mild discomfort and as result anxiety is also minimal or none. Sixou et al examined pain levels with the use of Quicksleeper in 50 children by using the VAS and concluded that most children felt no pain or only experienced slight pain.[3] They also reported that approximately 58.9% of children who had experience with traditional syringe anesthesia, preferred Quicksleeper as it was more comfortable and therefore patients had less anxiety regarding the injection.[3] Marques-Ferreira et al. selected 32 healthy individuals to compare periapical infiltration anesthesia with intraosseous Quicksleeper and established that most individuals did not feel any pain, but a small number of participants did have mild post-operative discomfort.[32] When performing dental injections, dental anxiety is the main co-variable in patient cooperation and emotion. This anxiety can cause the patient to experience more pain, even if the injection itself is less painful. An anxious patient can cause increased muscle tension and disruptive behaviours that ultimately lead to a less pleasant anesthetic experience. A study performed by Hembrecht et al. compared two types of computerized injection systems, SleeperOne and the Wand, to test the levels of pain-related behaviour in children between a first and second treatment appointment.[24] The results showed that even though SleeperOne had a significantly shorter injection time (2.49 min), compared to the Wand (3.2 min), the patient continued to show high levels of pain and distress during the sequential dental treatment session.[24] This study further concluded that the device used for injection did not have an impact on pain and stress related behaviour, and there was an overlying psychological factor involved in the patient's response to the injection systems.[33] Computerized systems aid in controlling pain while at the same time making the patient comfortable and cooperative.[34] Colares et al., found in a study that most fear and anxiety amongst children in a dental setting were in direct connection to injections.[26] Because of this, avoidance of treatment/checkups was prevalent. 41/67 cases reported a heart rate higher after delivery with the conventional method due to the fear and anxiety associated with the appearance needle. A method to make the injection less daunting is what brought about the design and function of the STA. Similar to the SleeperOne, the needle is camouflaged to fit into a pen-like holder attached to a central computerized docking station. San Martin-Lopez et al. concluded that the Wand

and other digital systems of local anesthesia are much better tolerated than conventional systems.[26] Visually induced anxiety that is instigated when a patient encounters a conventional syringe system is put to ease with the friendly-looking design of the Wand.[24] There is a direct correlation between pain/anxiety and the change in blood pressure and heart rate as they are directly proportional. The local anesthetic injection induces fear and anxiety amongst patients and consequently activates their sympathetic nervous system to elicit a heightened heart rate and blood pressure. When comparing heart rate and blood pressure, both are stable amongst patients treated with the STA Wand compared to those with the conventional local anesthesia needle. Previous study concluded that 86.11% of patients that received STA injection were less anxious.[28] With the STA Wand, pain upon administration encompassing insertion of the needle and flow of the anesthetic at the site was less than when compared to the traditional method reported by Jalevik et al. overall implying less anxious and more compliant patients.[28] Stress signals of patients associated with needles and injections were lower in the presence of the STA Wand compared to that of the conventional needle. The Wand is friendly to the eye and the needle can be hidden during administration. It mimics the look of a pen which puts patients, especially of a young age group, at ease as it does not provoke fear like the appearance of a conventional needle.[24] When the anesthetic onset is faster, patient stress is significantly less because there is no pain that is perceived. The height of anxiety is therefore reduced and treatment can therefore continue in a timely and efficient manner. When performing the intraligamentary method with the computerized systems, additional anesthesia to achieve the desired effect is not necessary. The result of this is a more comfortable and pain-free experience for the patient, resulting in higher patient satisfaction and cooperation for current and future treatments.[35]

Other postulated advantages and disadvantages

Aside from the local anesthetic conventional syringe being available in every dental office, and the practice and skill in using the conventional syringe comes in basic dental studies and training, there are some other advantages of the classic local anesthetic technique. Being the most affordable and universally known equipment in the dental office setting, the conventional syringe can anesthetize any location in and around the oral cavity, depending on the type of injection technique used. In a study by Özer et al., it is found that a longer duration of anesthesia is performed with the use of the conventional syringe compared to the computer-controlled system (Quicksleeper). This traditional technique is particularly more useful for longer surgical procedures.[4] Quicksleeper is recommended for minimally invasive procedures due to the short duration of anesthesia. Sixou et al. concluded that successful treatments such as pulpotomies and extractions could be completed in the primary dentition and 91.7–100% of restorative treatments, pulp capping, and scaling in the permanent dentition.[8] Although, this data must be viewed with caution as children who were non-compliant or had teeth that showed signs of physiological or pathological bone resorption were not included.[8] One main advantage of Quicksleeper is its ability to anesthetize the targeted tooth without affecting surrounding structures or adjacent teeth. In comparison to the IANB with traditional syringe anesthesia, Quicksleeper can achieve profound anesthesia without numbness of the cheek tissues or lip.[1] In comparison to traditional syringe anesthesia, the analgesic effect of Quicksleeper is rapid, owing to the direct injection of local anesthetic into the cancellous bone of the target tooth.[3] A study conducted by Beneito-Brotons et al. demonstrates that the onset of Quicksleeper is immediate with the following results of 7.1±2.23 minutes (range 3–14) for conventional technique and 0.48±0.32 minutes (range 0–4) with intraosseous anesthesia; the difference between both techniques are statistically significant.[2] Owing to the design of Quicksleeper it is possible to deposit the solution using similar injection methods as conventional syringe anesthesia such as transcortical, osteocentral, periodontal ligament injection (PLE), intraseptal injection, infiltration, and nerve block anesthesia.[2] Sovatdy et al reported that Quicksleeper requires less anesthetic solution when compared to the traditional IANBI technique.[1] Various studies have reported the Quicksleeper as being painless or less painful when compared to conventional anesthesia due to the asymmetric triple bevel of the needle tip which allows for easy perforation into bone.[2] The SleeperOne is a computer-controlled system that regulates the amount of analgesic fluid injected over a given period. It does so by running on a system called the permanent analysis of resistance (PAR), which controls the injection according to the density of the tissue. This allows the pressure within the tissue to remain low to not exceed the pain threshold.[36] It also allows for a quicker injection time at an average of 2.49 minutes.[10] The SleeperOne is also equipped with a double-beveled needle that makes it easier to penetrate bone when performing an intraosseous injection, specifically in children.[24] It is advantageous compared to its competitors as it has a pen grip for a more precise injection and has four injection speeds that can be controlled with a wireless foot pedal.[36] In a study by Garret-Bernardin et al. it was found that most fear and anxiety amongst children in a dental setting were in direct connection to injections.[26] With the less daunting appearance of the STA Wand, acceptance and cooperation with its use serve as a big advantage. The computerized anesthesia system can deliver

anesthetic solutions to administration sites at a slow and controlled flow rate much below the threshold level known to elicit pain.[27] The practitioner using the system is provided with perceivable and constant indication/feedback of being in the correct anatomical location allowing for efficient delivery and results obtained immediately.[28] This not only makes the deposit of anesthesia effective but also means that clinicians can begin their work immediately and waste no time; overall treatment duration is consequently shortened. The use of the STA Wand is for intraligamentary injections but can be used for all other methods as well inclusive of local infiltrations and nerve blocks. With the intraligamentary technique, it poses as a huge advantage in that inhibition of sensation is extremely localized without affecting neighboring structures such as the tongue and cheek. Less anesthetic solution is often observed to be needed to deliver the same profoundness of effect resulting in less toxicity risk, quick regain of sensations, and overall safety to use amongst healthy as well as medically compromised patients. With the ability to be such a localized form of anesthetic delivery, it is beneficial to both the patient and the dentist that they can have work done and operate on multiple regions of the mouth at the same visit. The success of conventional syringe anesthesia does not simply depend on a set of specific requirements. Hannan et al. studied needle placement for the inferior alveolar nerve block technique and concludes that accuracy of needle placement does not guarantee pulpal anesthesia.[37] Although operator skills such as excellent knowledge in intraoral anatomy, and variations in the location of important injection point landmarks are advantageous, there are many other factors influencing the success of the conventional syringe. Anatomical factors such as accessory innervation and soft and hard tissue barriers to diffusion influence the advancement of local anesthetic solution in which it can be found as unpredictable.[38] Equipment related factors, such as deflection of needle tip and needle gauge, pathological state factors such as pulpal pathologies, and patient's psychological state factors related to administration of local anesthetic and dental procedures, are influential, too.[5,39,40] Cetkovic et al. also mentions that having precise manual control over pressure gradients and flow rate by the operator during injection can be difficult to achieve and may negatively influence the success rate of the anesthetic solution diffusing through alveolar and palatal bone.[14] Overall, the advancement of local anesthetic solution is unpredictable due to a combination of all or some of these factors. In addition to the mentioned disadvantages, second injections and greater amount of anesthetic solution is needed compared to newer methods.[13] Quicksleeper is not recommended for procedures that are complicated or require longer than 60 minutes. Jensen et al conducted a study that showed the aaesthetic effect of Quicksleeper began to reduce at 30 minutes and was practically zero at 60 minutes.[15] Similarly, another study concluded that one-third of patients where CAIOI was used required supplementary anesthesia due to inadequacy.[1] Correspondingly the data shows the success rate of CAIOI was 68% and 72% for IANBI.[1] Therefore, with the use of Quicksleeper a greater concentration of epinephrine should be used to maintain profound anesthesia in bone for procedures that last longer than 30–45 minutes.[8] For surgical operations that required longer than 20 minutes such as removal of impacted third molars, Quicksleeper should not be used as the chances of hemorrhage are greater due to the shortening effect of anesthesia.[2,4,22] Many practitioners prefer the use of vasoconstrictors as it produces a long-lasting and confined anesthetic effect, however, a possible side effect can be increased heart and pulse rate in patients where Quicksleeper was used.[4] In contrast, two studies showed no increase in heart rate with 4% articaine with adrenaline, 1:100,000 with the use of Quicksleeper.[32] Hence, more data is required to sufficiently understand the effect of epinephrine on heart rate with the use of IO injections. Another drawback of Quicksleeper is the application itself takes longer than with conventional techniques, and when combined with the short analgesic effect it may not be the first choice for lengthier procedures.[4] Whether conventional syringe anesthesia or Quicksleeper is used, there is a possibility of unwanted lesions occurring. Siwawut et al. concluded that within their study 10% of patients had developed aphthous ulcers near the injection site a few days after the procedure.[6] Likewise, Graetz et al. established that osteonecrosis, external root resorptions, irreversible pulpal lesions, and/or periodontal lesions may occur in some circumstances.[41] The SleeperOne is aided by an automated anesthetic drop that is fast-acting. This sponsors as a disadvantage as there is a slight learning curve with dentists who are less practiced using this injection system as they might add more anesthetic than planned.[24] The SleeperOne is advertised as a painless injection system, studies mentioned previously prove this to be inaccurate as there are signs of distress and pain while injecting. Although the injection itself may not be as painful, according to the theory and study by Hembrecht, the consecutive deliverance of a local analgesic injection may condition a child's fear response.[24] In addition to this conclusion which was deemed true, it was also proven that even if the system was switched to a different device with which the patient has no experience, they still showed a degree of distress and pain-related behavior.[24] The SleeperOne's anesthetic cartridge is located within the handpiece causing it to be heavier and bulkier than its competitors.[33] It also does not feature a needle that rotates unlike its competitor, the Quicksleeper system, and therefore is unable to perform trans-

cortical and osteocentral injection techniques.[33] The STA Wand can be seen as an investment as it is an additional expense that needs to be considered. Its machinery, though simple, is bulky and requires extra space within an operating room.[28] In places with tighter space availability, the docking station and computerized screen, and the device's needle pen to which it connects to are quite bulky. Apart from purchasing the machine, device-specific needles also have to be purchased for its use, a cost that clinicians need to consider.[28] The length of the cable between the needle pen and the machine also can come in the way of administration and presents as additional clutter in an already compromised area. Lastly, there comes a learning curve associated with the use of the STA Wand system, and a time period before its use can be maximally beneficial.[25]

Comfort and safety of use

In addition to excellent knowledge of intraoral anatomy and variations of injection landmarks, manual control is essential for a comfortable dental procedure for both the operator and the patient. Velasco et al describe that decreasing the speed and pressure of the injection is an effective approach to decreasing pain levels for the patient, but it is a strenuous method for the operator.[42] Needle breakage during administration is a rare and serious complication, not only for the patient but for the operator as well because legal action may be acquired. Awareness and knowledge by the operator of the safety of use of the conventional syringe are important to avoid needlestick and sharp injuries. The use of Quicksleeper does require the clinician to properly examine the working field, take periapical radiographs to determine where the root is located, and determine if any protrusions of the cortical bone exist.[41] Therefore, having adequate knowledge regarding the use of this device as well as the patient's anatomy is extremely crucial.[41] The application time of Quicksleeper is longer when compared to conventional syringe anesthesia due to the components of the device and requires perfected insertion techniques to avoid causing pain or injury.[4] SleeperOne works on a dynamic feedback mechanism that regulates the injection according to the density of the tissue.[32] This leads to a faster average delivery time and because of this, is expected to have a higher comfort for the patient and the dentist. It provides the dentist with a handpiece that looks like a pen as opposed to a syringe grip to ensure a more accurate and precise injection.[36] At the same time, this grip is bulkier than competing computerized anesthetic systems and therefore might be less comfortable than other automated injection systems.[36] The pain caused by the administration of local anesthesia mainly arises due to the puncture of the needle. Computerized injection systems were created to address this.[28] The comfort and ability to use the STA Wand for methods of administration beyond just intraligamentary PDL injections implies convenience as devices do not have to be changed to establish the necessary level of effect desired.[26] During the initial administration of anesthesia, when compared to the conventional syringe, the STA Wand is reported to have a lower pain sensation. Furthermore, the efficacy or intended result in regards to depth of anesthesia results as adequate for both. The STA system can achieve local anesthesia to specified areas in the mouth, and as a result, multiple sites of the mouth can be treated simultaneously without compromising the safety of the patient. This serves as a great alternative to the conventional syringe nerve block method.[25] The administration of the anesthetic is very slow allowing for the perception of pain to be nullified. The numbing effect is extremely localized without extending to the cheek/tongue, therefore, eliminating common post-treatment cheek/lip biting trauma. Furthermore, the depth of necessary anesthesia is achieved more efficiently in regards to timing, location as well as overall toxicity as less solution is required.[26] The effects of anesthesia take longer to wear off with the block and can be very uncomfortable for the patient. No complaints or complications were reported with the ILA technique. With regards to the ILA technique, by the end of the treatment, the effect of the anesthetic is worn off and the patients' sensations are reported as normal.[43]

Limitations

Considering the previously mentioned factors that influence the success rate of anesthesia with the conventional syringe technique, following the methods of administration correctly with accurate knowledge and placement of injection, as well as clinically evaluating successful anesthesia such as lip numbness, there can be other factors that may limit the success and efficacy of the conventional syringe technique. Results may vary due to pharmacological properties, variations in innervations, and anxiety and psychological factors.[14,37] As discussed previously, the Quicksleeper has many advantages and can be a great accessory for practitioners, although it does have some limitations. Marques-Ferreira et al. discussed in their paper that the Quicksleeper does have the potential to overheat, thus resulting in irreversible damage to the targeted tooth and surrounding structures.[32] With traditional syringe anesthesia, only a syringe and needle are required to deliver the anesthetic solution while the Quicksleeper uses a handpiece. Woodmansey et al reported that osteonecrosis occurred in an HIV-positive individual with the use of diploe anesthesia because of the heat that was generated by the needle upon delivery of the solution.[44] Therefore, the rotation speed of the Quicksleeper should be monitored and kept to 11,000 rpm to avoid such situations.[44] Another limitation of Quicksleeper is reduced space in the operative field for the insertion of the needle. Graetz

Table 2. Advantages and disadvantages of conventional syringe and Quicksleeper, SleeperOne, and The Wand

Local anesthetic equipment	Advantages	Disadvantages
Conventional syringe	· Longer duration of anesthesia that is useful for longer surgical procedures.[4] · Can anesthetize any location depending on injection technique.[43] · Universally known and learned in dental university education.[4]	· The advancement of the local anesthetic solution is unpredictable, no matter the accuracy of needle placement.[38] · Operator skills which come with experience are helpful in the success of the anesthetic, therefore knowing the intraoral anatomy and variations of landmarks for different techniques is critical, but accuracy of needle placement does not guarantee pulpal anesthesia.[39] · Factors that are limited in controlling precisely, such as pressure gradients and flow rate by the operator, may negatively influence the success rate of the anesthetic solution diffusing through alveolar and palatal bone.[14] · Greater pain of injection experienced.[1] · Second injections usually needed.[13] · Greater amount of anesthetic solution needed compared to new methods.[13]
Quicksleeper	· Recommended for minimally invasive procedures.[6] · Can anesthetize the targeted tooth only.[3] · Lack of lip and cheek tissue numbness.[1,3] · Analgesic effect is rapid and immediate.[3,4,8] · Injection methods used in conventional syringe anesthesia can also be used with Quicksleeper.[1,3,4] · Less anesthetic solution required.[1,8] · Painless or less painful.[1,3,4,22,33]	· Not recommended for procedures longer than 60 minutes.[2,4,22] · Shortening of anesthetic effect due to haemorrhage.[4] · Can produce increased heart rate.[4] · Duration of its application is longer than traditional syringe anesthesia.[4] · Osteonecrosis, external root resorptions, irreversible pulp lesions, aphthous ulcers and/or periodontal lesions may develop.[45]
Sleeper One	· Regulated flow of fluid.[36] · Low pressure within tissue.[36] · Quick injection time.[10] · Double beveled needle.[10] · Multiple injection speeds.[36]	· Learning curve.[10] · Hand piece heavy and bulky.[33] · Non rotating needle.[33] · Not eligible for osteocentral and transcortical injections.[33]
The Wand	· Decreased anxiety levels.[26] · Increased cooperation.[26] · Painless and less daunting appearance.[26] · Controllable and predictable delivery of anesthetic.[26] · Immediate onset of action.[26] · Quicker overall treatment duration. · Less toxicity (less amount of anesthetic needed to achieve the same depth of anesthesia with conventional method).[26] · Ability to perform all anesthetic methods with the same device.[26] · Ability to work on multiple areas at the same visit.[43] · Inhibition of sensation localized to one area without extending to the tongue and cheek.[24] · Quick regain of sensations.[43] · Can be used across all procedure types.[26] · Avoiding postoperative self-inflicted injuries tongue and lip biting for example.[45] · Safe to use in patients with underlying medical conditions.[46]	· Additional expense machinery.[28] · Inconvenient to have in areas where a lot of space is not available.[28] · Device specific needles are needed.[28] · Learning curve associated with its use.[24]

et al analyzed situations where dentists accidentally perforated the root while administering the anesthetic solution, therefore compromising the pulp and peri-radicular tissues of the targeted tooth.[41] Traditional syringe anesthesia may be preferred in scenarios with reduced visibility or space. Despite the friendlier look of the SleeperOne compared to the traditional syringe, it is still a needle, and patients, specifically younger children that have anxiety with needles might still cause trouble for dentists during the anesthetic injection. As mentioned previously, a large factor that affects the pain of dental injections is patient anxiety. It seems that although the injection itself is designed to be less painful due to the C-CLAD's technology, the patient's anxiety levels cause there to be no significant difference in the experience of pain whether the dentist is using the SleeperOne or not.[10] The SleeperOne consists of a lead control box and a foot pedal that is connected to a handpiece, which is where the local anesthetic carpule is located. Because of this, the handpiece is bulkier than its competitors such as the Wand, and maybe more uncomfortable to hold for the dentist.[33] It also requires more equipment compared to the conventional syringe. The access and availability to the STA Wand device present a limitation of using the STA intraligamentary technique with the Wand. It is an extra piece of equipment that one would have to invest in for use at their clinic. Additional to the purchase of the machinery, further functional pieces with specific needle attachments need to be bought.[26] To be able to optimize its results, a practitioner must first and foremost also learn how to use it. Clinicians can pick up on this quite rapidly but it still poses a limitation compared to the conventionally taught ease of using a standard carpule syringe.[23] Table 2 summarizes the advantages and disadvantages of using conventional syringe anesthesia as compared to CCLAD.

Conclusion

Anxiety associated with dentistry, specifically due to the fear of needles, instigated curiosity to find out whether computer-assisted anesthetic devices including STA Wand, Quick Sleeper, and SleeperOne could potentially replace the use of the conventional daunting anesthesia syringe. Comparing factors associated with the anxiolytic effect, longevity, profoundness of anesthesia, accessibility, as well as overall practicality of use, positive outcomes have been able to be observed. Furthermore, it can be noted that all computerized methods can deliver anesthesia by conventional methods (nerve block and local infiltration) but additionally by intraligamentary and intraosseous techniques. The use of these devices encompasses all treatment/procedure types and is well tolerated by their recipients. Drawbacks inclusive of additional material and equipment expense, the training and learning curve, and availability of these devices are elements that indicate further research necessary to determine whether or not computer-assisted anesthetic devices can substitute the use of the conventional needle and syringe by dental clinicians.

Declarations

Funding

There are no external funding.

Author contributions

Conceptualization, N.S., J.Y. and S.W.,K.B; Resources, N.S.,S.W., J.Y.; Data Curation, N.S.,S.W., and J.Y.; Writing – Original Draft Preparation, N.S., S.W., J.Y.; Writing – Review & Editing, K.B.; Supervision, K.B.; Project Administration, K.B.

Conflicts of interest

None conflicts of interest are declared.

Data availability

Data supporting the results of this study shall, upon appropriate request, be available from the corresponding author.

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