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ORIGINAL SCIENTIFIC ARTICLE

Intraosseous anaesthesia in children with 4 % articaine and epinephrine 1:400,000 using computer-assisted systems

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Abstract
Aim To assess retrospectively the efficacy of computer-assisted intraosseous anaesthesia (CAIO) in children using an anaesthetic solution with a lower concentration of epinephrine (1:400,000).
Methods In a retrospective study, CAIO was evaluated in healthy children and adolescents for restorative and endodontic treatments, uncomplicated tooth extractions or scalings using articaine 4 % plus epinephrine 1:400,000. Anaesthesia was performed in children who showed enough compliance (score of 0–3 according to modified behaviour Venham scale). Efficacy, amount of anaesthetic solution as well as need of a complementary injection was assessed.
Results A total of 421 consecutive sessions were performed on 278 patients aged 7.1 ± 2.9 years with 518 teeth involved in the anaesthetic process and analysed process. When teeth to be anaesthetised were considered, the overall success rate was 97.2 %. In most of the cases, only 0.9 mL was needed to achieve anaesthesia. Permanent teeth needed significantly more anaesthetics than primary teeth. Sensitivity of the teeth anaesthetized reappeared in 5.7 % of cases after 30–60 min of treatment.
Conclusions These results suggest that CAIO with 4 % articaine and epinephrine diluted 1:400,000 can be an alternative to usual infiltration techniques or IO with epinephrine at a higher concentration for most of treatments in primary and permanent teeth. Further studies are needed to evaluate its efficacy in permanent teeth in case of endodontic treatment or extraction.

Keywords Children · Computer-assisted dental anaesthesia · Intraosseous anaesthesia · Epinephrine

Introduction

Intraosseous (IO) injections consist of injecting local anaesthetic directly in the cancellous bone adjacent to any tooth to be anaesthetised. In young patients, passing the injection needle through the cortical plate or the interdental septum to penetrate into the spongy bone can be easily performed using any kind of injector. When both cortical plates or septae become thicker, three different kinds of devices can be used to penetrate: (1) perforators associated with usual injection through the perforation performed (Stabident™ [Fairfax Dental™], X-Tip™ [Dentsply/Maillefer™]), (2) devices associating dental handpiece-based rotation of a needle and different kind of injectors associated with the dental handpiece (Anesto™ [W&H Dentalwerk Bürmoos GmbH, Bürmoos, Austria], Intra-Flow™ [Pro-Dex Inc, Santa Ana, CA)]), (3) device using both computer-controlled rotation of the needle and computer-controlled injection of the anaesthetics (Quick Sleeper™ [Dental Hi Tec™, France]). Only this latter system has been tested on children in two studies showing that Computer-Assisted IO (CAIO) is a valuable alternative to traditional infiltration techniques in children with efficacy rates from 91.2 to 97.2 % (Sixou and Barbosa-Rogier 2008; Sixou et al. 2009). CAIO allows rapid and deep anaesthesia of teeth with little anaesthetic injected and no numbing of soft tissue resulting in a very low risk of self-biting (Sixou and Barbosa-Rogier 2008) and good acceptance by the

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patients (Sixou et al. 2009). Studies in adults also show good efficiency which devices are used (Dunbar et al. 1996; Nusstein et al. 1998; Guglielmo et al. 1999; Stabile et al. 2000; Gallatin et al. 2003; Jensen et al. 2008; Remmers et al. 2008; Beneito-Brotons et al. 2012; Özer et al. 2012; Pinto Pereira et al. 2013) except when vasoconstrictors were not associated with the anaesthetising solution (Replogle et al. 1997). On the other hand, epinephrine has been supposed to be associated with a higher risk of increased heart rate despite very contradictory data according to studies (Coggins et al. 1996; Dunbar et al. 1996; Lilienthal and Reynolds 1975; Replogle et al. 1999; Chamberlain et al. 2000; Stabile et al. 2000; Gallatin et al. 2003; Wood et al. 2005; Bigby et al. 2006; Susi et al. 2008; Peñarrocha-Oltra et al. 2012; Pinto Pereira et al. 2013). This effect on heart rate could be injection speed- and device-dependent (Susi et al. 2008; Pinto Pereira et al. 2013). When using vasoconstrictors, all the studies performed in adults or children used either 2 % lidocaine or 4 % articaine associated with 1:100,000 to 200,000 epinephrine.

In 2012, a new anaesthetic solution with 4 % articaine and epinephrine 1:400,000 was introduced in France. Its low epinephrine concentration made it interesting for use in young patients with a lower potential risk of side-effects such as increased heart rate. It then became the anaesthetic used for intraosseous anaesthesia in the Department of Paediatric Dentistry of the Dental Hospital of the University Hospital of Rennes (DPDR). It therefore became interesting to know whether its use in CAIO in children could lead to an efficacy rate similar to that of previous studies.

The aim of this study was to evaluate its efficacy in a retrospective study based on the analysis of data from consecutive patients attending the DPDR.

Materials and methods

Population

Data from 278 consecutive children and adolescents aged 3–16 years of age attending the DPDR during a 5-month period (Table 1) were analysed by two practitioners (JLS and AMC) in this retrospective study. Patients with a severely impaired condition (ASA score above II) were not included as well as children whose behaviour was not cooperative [Venham modified score (Collado et al. 2006) above 3] or who were already taking analgesics or anti-inflammatory drugs. Children who became non-compliant during anaesthesia or treatment (modified Venham score of 4 or 5) were excluded from the analysis. Local anaesthesia was evaluated for teeth needing conservative or endodontic treatments or extraction that did not need additional mucosal or osseous surgery. Teeth with regional inflammation such as cellulitis, inflammatory or physiological bone resorption were excluded as well as MIH teeth. These latter teeth are included in another protocol in the department of paediatric dentistry.

Table 1 Population studied and sessions performed

	Male	Female	Total
Patients (*n*)	150	128	278
Sessions performed	214	207	421
3–6-year-olds	100	97	197
7–10-year-olds	84	78	162
11–16-year-olds	30	32	62

Computer-assisted intraosseous injection

CAIO was performed by two trained teachers of the DPDR (JLS and AMC) using a routine protocol implemented after the end of the initial evaluation of the method (Sixou and Barbosa-Rogier 2008; Sixou et al. 2009) using the Quick Sleeper 4™ system (Dental Hi Tec™, Cholet, France). Briefly, after anaesthesia of the buccal attached gingiva, the needle was inserted at a 90° angle to the gingival buccal surface (transcortical intraosseous anaesthesia) in order to be in contact with the cortical plate. Penetration into the spongy bone was performed by simply pushing the needle when the cortical plate was thin enough or by computer-assisted rotation of the needle when the cortical plate was too thick to allow penetration by simple pressure.

After penetration in the spongy bone, computer-assisted injection of the anaesthetic solution was performed. In posterior teeth, the needle was inserted through the septum (osteocentral intraosseous anaesthesia) to allow easier access. Intraosseous penetration was performed with or without needle rotation as in the transcortical method. In children below 6 years old that have thin cortical plates or interdental septae, the Sleeper one™ system (Dental Hi Tec™, Cholet, France) was used. This latter system was thinner than the Quick Sleeper 4™ system. It also allows computer-assisted injection of the anaesthetic solution but did not allow needle rotation. According to previous results (Sixou and Barbosa-Rogier 2008) half of the cartridge (0.9 mL) was injected in a first step. Anaesthesia was then checked by gentle pressure within the buccal and palatal/lingual sulci of the tooth or teeth to be treated using a smooth carver. When no sensitivity was detected, the treatment was performed. Additional solution was added by CAIO if needed up to 1.8 mL (full cartridge) or 2.7 mL (1 cartridge and a half) when sensitivity persisted during checking in sulci or during treatment.

Treatments were then performed by 5th- and 6th-year dental students working in the DPDR.

Statistical analysis

Data were collected on a PC computer. Anaesthesia was rated as success when treatment could be achieved without pain. Anaesthesia was rated as failure when treatment could not be performed because of pain or without a complementary anaesthesia other than adding anaesthetic using CAIO.

Success rates were evaluated at respectively 0.9, 1.8 and 2.7 mL injected. The results were analysed using the Chi square with significance set at $p < 0.05$.

Results

A total of 421 consecutive sessions were performed on 278 patients aged 7.1 ± 2.9 years with a median age of 7 (Table 1), with 518 teeth involved in the anaesthetical process and analysed. CAIO sessions were performed to anaesthetize primary teeth (286) or permanent teeth (133) or primary and permanent teeth (2).

At the beginning of the sessions, patients were mainly not or slightly anxious (62.7 % with modified Venham scores of respectively 0 or 1). Children aged [3–6 years] and [7–10 years] showed significantly higher score of 2 or 3 than those over 10 years (respectively $p = 0.00007$ and $p = 0.00026$), with no difference between the two younger age groups or between males and females.

CAIO was performed without needle rotation in most cases when performed on primary teeth and mainly required a single needle rotation for permanent teeth (Fig. 1). The difference between primary or permanent dentition was highly significant ($p > 0.00001$). There was no difference according to gender.

The overall success rate of CAIO sessions was 96.2 % with similar rates for primary and permanent teeth and males and females (Table 2). When teeth to be anaesthetised were considered, the overall success rate was 97.2 % (504/518) (Table 3). The success rate was similar for most type of treatment performed (Table 3) save when "endodontic treatment" or "extraction" were compared to "medium depth restorative treatments" or "other treatments" in permanent teeth ($p < 0.05$).

The volume of anaesthetic solution needed to achieve successful anaesthesia was evaluated for 405 sessions involving 501 teeth. In most of cases only 0.9 mL was needed (Tables 3, 4). In 3 sessions, 0.9 mL were enough to anaesthetize one tooth but 0.9 mL more were needed to achieve anaesthesia of another tooth in the same session.

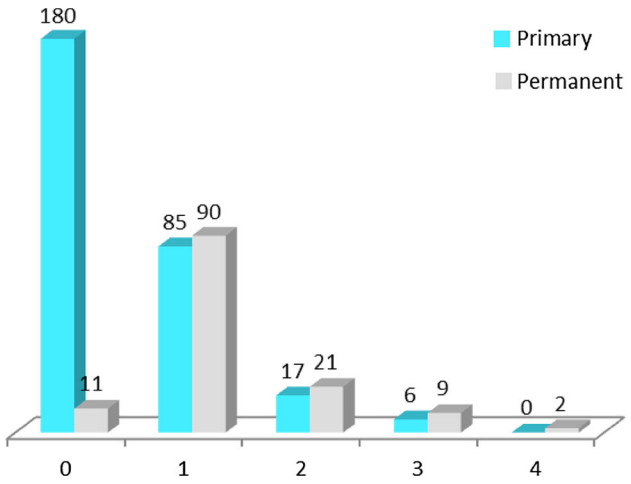

Fig. 1 Distribution of sessions according to the number of needle rotations needed to penetrate the bone in primary and permanent teeth. "0" means "no needle rotation needed to penetrate the bone". Primary teeth: total of 288 sessions including 286 sessions on primary teeth and 2 sessions on both primary and permanent teeth

Table 2 Success rates of CAIO sessions in the population studied

Sessions	*n*	%
Total	405/421	96.2
M	207/214	96.7
F	198/207	95.7
Primary teeth[a]	278/286	97.2
Permanent teeth	127/135	94.1

[a] Sessions in primary teeth: including two sessions with both primary and permanent teeth treated

Table 3 Volume of anaesthetic needed to achieve anaesthesia according to treatments

	n	Success (%)		
		0.9 mL	1.8 mL	2.7 mL
Primary teeth				
Restorative (medium depth)	71	84.6	100.0	–
Restorative (deep caries)	71	76.1	97.2	100.0
Pulp capping	12	75.0	91.7	–
Pulpotomy	131	62.6	84.0	95.4
Extraction	69	66.7	92.8	100.0
Total	354	70.1	92.1	98.0
Permanent teeth				
Restorative (medium depth)	46	76.1	91.3	100.0
Restorative (deep caries)	42	38.1	85.7	97.6
Pulp capping	13	61.5	69.2	100.0
Endodontic treatment	29	48.3	65.5	82.8
Extraction	7	28.6	71.4	71.4
Other treatments	27	40.7	100.0	–
Total	164	52.4	84.1	95.7

Table 4 Volume of anaesthetics needed to achieve anaesthesia

Sessions	0.9 mL	1.8 mL	2.7 mL
Primary	200	55	20
Permanent	74	34	19
Total	274	89	39
	68.2 %	22.1 %	9.7 %

Primary teeth: data on 275 sessions (instead of 278). In three sessions involving two primary teeth, 0.9 mL was enough for one tooth and 1.8 mL needed for the other

Permanent teeth needed significantly more anaesthetic than primary teeth ($p = 0.0049$).

Among the 405 successful sessions, the sensitivity of the teeth anaesthetized reappeared during treatment in 23 cases (5.7 %) involving significantly ($p = 0.0023$) more permanent (14) than primary teeth (9) representing respectively 3.3 % and 10.4 % of the sessions. This sensitivity was noted after 30–45 mn of treatment in 19 sessions (4.7 %) and after 60 min in the 4 others involving permanent teeth. It was not related to any particular kind of treatment. In these cases, some additional anaesthetic was given to the patients to allow students to achieve the treatment.

Discussion

Dental anaesthesia in children and adolescents can be challenging. CAIO is a promising method but few studies are available on children. Furthermore, as in any injection of epinephrine-containing solution, it might be associated with increased heart rate and other side effects such as dizziness, pale skin, shakiness and headaches. IO is known to be associated with delayed diffusion in serum compared to infiltration techniques and associated with higher blood levels of the anaesthetic injected (Wood et al. 2005). Although the real effect of epinephrine on heart rate associated with IO injections remains controversial, using a lower concentration of this vasoconstrictor might be safer.

In the present study, CAIO with 4 % articaine and 1/400,000 epinephrine showed high success rates when used on both primary (97.2 %) and permanent (94.1 %) teeth. These rates are close to those previously published (respectively 95.0 and 87.9 %) using 4 % articaine and 1/200,000 epinephrine (Sixou and Barbosa-Rogier 2008), suggesting that decreasing the concentration of epinephrine does not result in a loss of efficiency in short-time dental routine treatments. Furthermore, a single 1.8 mL cartridge or less was enough to allow one or more teeth to be treated in 92.1 % (primary teeth) or 84.1 % (permanent teeth) of the sessions. Restorative treatments, pulp capping, scaling (included in "other treatments") could be achieved in 91.7–100 % of cases in both dentitions and pulpotomy and extraction in the primary dentition. However, those results have to be analysed in the framework of the protocol used. Non-compliant children were not included and teeth with physiological or pathological bone resorption were excluded although those teeth were included in the previous studies with CAIO in children (Sixou and Barbosa-Rogier 2008; Sixou et al. 2009). The presence of bone is necessary to maintain the injection solution injected in the area adjacent to the target teeth to anaesthetize and teeth with resorbed bone are not considered for CAIO in the protocols used in the DPDR. The low number of extractions of permanent teeth included in the study did not allow definitive conclusions about teeth to be drawn. Few studies are available to compare the success rates obtained with this anaesthetic solution. In prospective non-interventional studies evaluating customary infiltration techniques for routine dental treatments, dental anaesthesia with 4 % articaine and 1:400,000 epinephrine was sufficient to perform the planned treatments in 93.5 % of children (Kämmerer et al. 2013) and 97 % of adults (Daubländer et al. 2012).

In 4.7 % of the sessions of the present study, tooth sensitivity was noted after 30–45 min, requiring further administration of anaesthetics. Treatments were performed by students which may partly explain why some of the treatment sessions were still ongoing after 30–45 min. A similar need of additional injection during treatment was described in respectively 3.1 and 3.7 % of cases in children (Kämmerer et al. 2013) and adults (Daubländer et al. 2012) when using routine infiltration techniques with 4 % articaine and 1:400,00 epinephrine. However, in one of the previous studies performed in children, the mean treatment time was 15 min, never exceeding 30 min. In the present study, no further injection was needed during the first 30 min of treatment. On the other hand, this reappearance of tooth sensitivity was not noted in a previous CAIO study performed with a 1:200,000 dilution of epinephrine associated with 4 % articaine (Sixou and Barbosa-Rogier 2008). This suggests that in cases where anaesthesia should be deep and with a duration above 30–45 min, a higher concentration of epinephrine should be preferred. This would allow anaesthetic to be maintained longer at efficient concentration within the bone adjacent to the teeth treated. This study also suggests that CAIO performed with a 1:400,000 dilution of epinephrine associated with 4 % articaine is less efficient in permanent teeth in case of endodontic treatment or extraction (respectively 82.8 and 71.4 % efficacy rates). (Özer et al. 2012) suggested that CAIO could be inadequate for prolonged surgical procedures in adults because of a lack of duration.

Conclusion

Computer-assisted intraosseous anaesthesia with 4 % articaine and epinephrine diluted 1:400,000 can be an alternative to usual infiltration techniques or IO with epinephrine at a higher concentration for all treatments in primary teeth and for restorative treatments in permanent teeth especially when treatments do not exceed a duration of 30 min.

Compliance with ethical standards

Informed Consent For this type of study formal consent is not required.

Conflict of interest The authors declare that no relationships or interests influenced or biased their work.

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