A new method for deep caries treatment in primary teeth using ozone: A retrospective study

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ABSTRACT

Aim *The aim of this study was to assess the effectiveness of a new protocol for deep caries treatment in deciduous teeth based on: 1) the incomplete removal of carious dentin tissue; 2) the use of new technology (ozone) for the disinfection of carious dentine; 3) the creation of a peripheral seal in healthy tissue for bonding procedures with rubber dam isolation.*

Materials and methods *From a personal database, authors selected 50 consecutive patients (28 males, 22 females; mean age 5.8 ± 1.7 years) in whom this new protocol was applied on posterior deciduous molars, for a total of 94 restorations.*

Results *Regular follow-ups were performed at 3, 6 and 12 months by a second operator, who was asked torate each restoration as success or failure. The success rate at 12 months was 93,62% (n. 88/94 restorations), similar to that reported in the literature for pulpotomy.*

Conclusion *The deciduous teeth considered for this study, if treated conventionally, would have probably been subjected to pulpotomy, because of the extension of the carious lesions. The proposed protocol, through the use of ozone, proved to be an excellent alternative, with the fundamental advantage of saving dental tissue and preventing the invasion of the pulp chamber.*

Keywords *Deep caries; Ozone; Primary teeth.*

Introduction

In recent years the use of new technologies for the treatment of tooth decay in young patients has revolutionised the world of paediatric dentistry. New approaches to ultra-conservative treatment of deciduous teeth include the use of ozone gas. Ozone, a substance already known in general medicine for its high disinfecting power, has been studied for its possibilities in dentistry since the 30s [Olivi and Olivi, 2007].

Ozone is a powerful oxidising agent occurring in nature as the trivalent oxygen (O3); it is a colourless gas with a pungent odour. Ozone has a very high disinfecting power: it is able to effectively kill bacteria, viruses and spores in a few seconds.vAfter the first experiments, the use of ozone had been abandoned because of toxicity, since no way had been found to concentrate the gas without waste. The studies were resumed in the 80s, when Dr. Edward Lynch of the Royal London Hospital Medical College demonstrated how a carious lesion exposed to a single application of the gas could re-mineralise [Lynch, 2004]. Later in recent years, the introduction of new devices has made it possible to apply gas directly on the tooth surfaces affected by early caries, thanks to special single-patient silicon cups [Baysan and Lynch, 2006]. The first device for dental use, after obtaining a vacuum inside the silicon cup mounted on the dedicated handpiece, was capable of delivering pure ozone starting from ambient air, conveying it to the wound, aspirating gas and converting it back to O_2. Recently a new device (Healozone X4*) was developed which is able to produce ozone taking it from a special canister of O_2, and transform it into a concentration of 32 g/m^3, with efficacy and power much higher than earlier devices.

Ozone fields of application are:

- caries of deciduous teeth;
- initial lesions in permanent teeth just erupted, when it is not possible to perform any type of restoration or sealing;
- primary fissure caries;
- root caries;
- sterilisation of endodontic cavities;
- sterilisation of prepared teeth before final cementation;
- desensitisation;
- treatment of periimplantitis;
- increased effectiveness of tooth whitening;
- promotion of the healing of mucosal lesions (e.g. herpetic lesions).

Given the ease of use and the absolute comfort of the method, the use of ozone has often focused on decontamination of carious dentin, especially in deciduous teeth of very small or non-cooperative patients, followed by the application of various products in order to obtain the re-mineralisation of the surfaces [Samuel et al., 2016].

The purpose of this study was to evaluate the clinical efficacy of a new procedure for deep caries treatment in posterior deciduous teeth that with a traditional approach would have probably been subjected to pulpotomy.

Materials and methods

From the database of hundreds of patients treated by the authors with ozone, a retrospective selection of those treated with the new protocol for deep caries lesions was performed.

The inclusion criteria were:

- presence of extensive lesion clinically evident on a deciduous posterior tooth (D or E);
- absence of evident signs of irreversible pulpitis (pus, fistula, pulp tissue exposed);
- absence of radiographic bone involvement or resorptions;
- absence of pain or history of mild pain caused by chewing or food impaction;
- tooth sensitivity;
- tooth at least 2 years from exfoliation (assessed either by age or radiographically);
- pre-, intra- and post-operative photographic documentation;
- reconstructive technique according to the new method proposed by the Authors;
- follow-up of at least 12 months.

In total, 50 consecutive patients (22 females, 28 males; mean age 5.8 ± 1.7 years) who has been treated by the same operator, for a total of 94 fillings, were selected. All patients has signed a specific informed consent for the treatment. The approval of the Ethics Committee was not asked because the procedure was considered absolutely safe and not invasive and was planned according to the World Medical Organization Declaration of Helsinki.

The protocol consists of the following:

- partial removal of carious dentin;
- sterilisation of the remaining tissue by ozone;
- compostite restoration under isolation of the operative field with a rubber dam.

The operating sequence applied in all restorations was the following.

- Isolation of the working area with rubber dam (limited to teeth E-D with hook on the most distal tooth).
- Cleaning and definition of the cavity margin in the enamel. For mesial or distal very deep cavities, it was agreed to have the cervical margin of the box within the dentin as long as well isolated with a sectional matrix (Fig. 1B–C).
- Removal of the top layer of carious dentin using rosette burs, without uncovering the pulp tissue. In fact, proper cleaning of all the cavities would have most likely implied an endodontic treatment.



FIG. 1 A Initial pre-operative view. B-C After rubber dam isolation and partial dentin removal, it's possible to appreciate the presence of enamal on cervical margin. Probably, the the perfect removal of all carious dentin would have determined a pulpotomy of E.



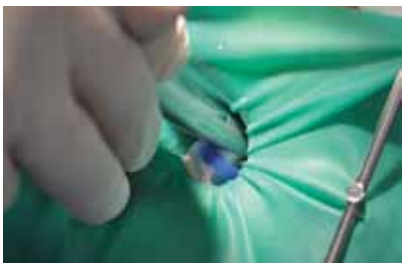

FIG. 1 D Light curing dam can be used to get proper insulation for the heal ozone silicon cup. E Ozone application.
F The use of sectional paedodontic matrix to create the correct interproximal contact.



FIG. 1 G The final restoration. H Occlusal view at the end of treatment. I 12 months follow up.

FIG. 2 A Initial deep lesions on D-E decidous elements.
B Partial caries removal.
C Occlusal view at the end of treatment.
D 12 months follow up.

- Ozone application on the infected dentin for 60 s with single-patient silicone cup (Healozone™ X4). On mesial and distal cavities, where it was more difficult to obtain the vacuum, OpalDam™ light curing liquid dam was used to obtain proper insulation (Fig. 1D). Vestibular and lingual walls with this material were created to allow the correct positioning of the silicone cup, because Healozone is not able to to deliver gas without a complete vaccuum inside the cup, which must be obtained by an adequate seal of the cup itself.
- 3-step technique bonding (etching, primer, bonding - Optibond™ FL, Kerr).
- Restoration of the decayed tooth with composite resins (Enamel™ - Micerium).
- Polishing and occlusion check.

All 94 restorations were performed by the same operator with the aid of 4X magnification systems and fiber optic LED lighting.

In about 80% of cases, given the young age of the patients, nitrous oxide conscious sedation was to improve cooperation. This has also made it possible to limit the use of plexus anesthesia to very few cases, thanks to the possibility of obtaining superficial analgesia through nitrous oxide.

Results

Regular follow-ups were made at 3, 6 and 12 months by a second operator, who was asked to rate each restoration as success/failure.

Taking a cue from the criteria used by the United States Public Health Service (USPHS)], the presence of the following 7 items defined success.

- Restoration still in place.
- Absence of marginal microleakage.
- Absence of the restoration fractures.
- Presence of an interproximal contact (for Class II cavities).
- Absence of discolouration.
- Absence of pain.
- Absence of pus or fistulas.

The results at 12 months, summarised in Table 1, show a very high success rate of the proposed method. Subsequently, a revaluation of the 6 failed cases, highlighted that in 4 of them there was a minimal exposure of the pulp during the bonding procedures - not during the removal of the carious tissue. This can be explained by the fact that the vacuum created by the Healozone cup may have suctioned the pulp tissue where the residual dentine layer was extremely reduced. Once obtained the hemostasis of the tissue, a direct pulp capping was performed with calcium hydroxide and contextually we proceeded to the restoration according to the described method. In all 4 cases, at 7–15 days an asymptomatic fistula appeared near the treated tooth, therefore we proceeded to the endodontic therapy .

Discussion

The American Academy of Pediatric Dentistry has established that "the objectives of restorative treatment are to repair or limit damage from caries, protect and preserve tooth structure, re-establish adequate function, restore aesthetics (where applicable), and facilitate good oral hygiene" (American Academy on Pediatric Dentistry Clinical Affairs Committee-Restorative Dentistry Subcommittee and American Academy on Pediatric Dentistry Council on Clinical Affairs, 2008). The treatment of caries lesions in children is often very complex and the new technologies of paediatric dentistry can help the operator to improve the approach and prognosis with small patients.

The use of ozone has been proposed for a long time in general dentistry and paediatric dentistry in particular for its antimicrobial, virucidal, disinfectant and biocompatible properties [Gopalakrishnan and Parthiban, 2012; Samuel et al., 2016]. It also has anti-inflammatory, analgesic, immunostimulant properties and it promotes tissue regeneration. It is able to kill the bacteria in the carious lesion without excision of infected tissue, so no anaesthesia is needed, and for this reason

	n.	%
Treated teeth	94	
Success	88	93.62%
Failure	6	6.38%

TABLE 1 Follow-up at 12 months

it has found wide use in paediatric dentistry [Johansson et al., 2009]. In initial lesions, it is able to eliminate bacteria present in demineralised tissues and promote remineralisation through the deposition of calcium and phosphate ions. In fact, the smear layer present on the exposed dentin prevents the deposition of calcium and fluoride ions in the dentinal tubules: ozone is able to remove the smear layer, favouring the opening of the tubules and the consequent deposition of ions. Many studies are present in the literature on the effectiveness of ozone as a disinfectant in endodontics, thanks to its antimicrobial properties [Halbauer et al., 2013; Holliday and Alani, 2014; Plotino et al., 2016]. A systematic review of the literature conducted in the past by Brazzelli et al. [2006] based on the evidence available up to 2004 concluded that it was not possible to determine the actual effectiveness and the cost/benefit ratio of the new method, since there were no adequate studies. However, the authors stated that the topic was worthy of further study and research. On the other hand, it was shown that the simple decontamination of cavitated lesions is not an effective treatment in the long term. Johansson [2014] evaluated the effect of ozone and fluoride varnishes in deciduous carious molars and concluded that none of the proposed treatments is able to stop caries progression. Therefore, it is necessary to restore destroyed dental tissues in any case and not to limit the treatment to the classic use of ozone as a simple remineralising agent.

The "classic" caries treatment of deciduous molars with deep lesions is the complete removal of decayed tissue, often resulting in pulpotomy of tooth. This procedure is definitely longer and more complex, especially considering the collaboration of the young patients and their age: it should be considered that the average age of the patients included in this study was less than 6 years.

Despite the undoubted difficulty of a correct pulpotomy of deciduous teeth, the long-term results reported in the literature appear favourable. Gonzalez-Lara [2016] reports a success of 85% at 24 months, Yildirim [2016] indicates a much higher percentage: at 24 months, the clinical success of formocresol is 96.9%, of MTA 100%, of Portland cement 93.9% and of the derivatives of enamel matrix 93.3%. The results are similar to those reported by other authors [El Meligy et al., 2016; Goyal et al., 2016; Rajasekharan et al., 2016] who also placed the biodentine among the materials, with success rates comparable to those of the MTA. More modest are the success rates reported by Sonmez [2008] with a 2-year follow-up: 76.9% for formocresol, 73.3% for ferric sulfate, 46.1% for calcium hydroxide, and 66.6% for MTA.

The systematic review of Stringhini Junior et al. [2015] considered all publications on pulpotomy of deciduous teeth, including only 30 of them in the meta-analysis. The authors conclude that pulpotomy with MTA has a success rate of 94.6%, the one with formocresol of 87.4%, while there is no evidence to support the use of calcium hydroxide for deciduous teeth. As an alternative to pulpotomy in the deep carious lesions of deciduous teeth, indirect pulp capping could be considered, (using dentin bonding agent, calcium hydroxide, zinc oxide and eugenol, glass ionomer cement). However, a recent review of the literature by Smail-Faugeron [2016] suggests to avoid this technique for lack of evidence, although it recognises the importance of preserving as much tissue as possible and reducing the size of the cavity. It should however be considered, as already mentioned, that a correct pulpotomy involves a considerable waste of time, energy and requires a high degree of cooperation from young patients. Moreover, in everyday clinical practice the success rates are much lower than those reported in the literature. This could be explained by the fact that, in the routine practice of a private clinic the presence of a fistula on a treated tooth is considered failure even if pain is not present, while the absence of pain is one of the success criteria used in the published works. This different interpretation of success/failure might explain the difference between the clinical reality and published data. Also it should not be underestimated that the endodontic treatment of deciduous teeth can weaken the tooth structure or cause a more rapid rhizolysis.

To improve the prognosis of the treatment of deep caries, the partial removal of caries has been recently proposed by several authors [Blanchard and Boynton, 2010; Franzon et al., 2015] as a less invasive treatment that prevents pulp exposure. The reference article is undoubtedly the one by Alleman and Magne [2012], where the concepts of peripheral seal and the limit beyond which not to extend the removal of the infected dentin are emphasised. Though not mentioning the use of ozone and referring to permanent teeth, he had placed the emphasis on some important concepts as early as 2012, namely:

- creating a peripheral seal area in healthy tissue, possibly enamel;
- including a small carious dentin layer within the peripheral seal of healthy tissue;
- removing the infected dentin without exposing the pulp;
- inactivating the residual bacterial load;
- using appropriate adhesive techniques able to maximise the binding of adhesion of peripheral layer.

The technique presented involves the inactivation of bacteria by the application of a chlorhexidine solution (concentrations from 0.2 to 2%) or benzalkonium chloride (concentrations ranging from 0.1 – 1.5%) for 30 seconds. Our conclusion is that the preservation of the pulp tissue is of fundamental importance for long-term prognosis. In the present study we have therefore tried to create a simple, effective protocol that takes into account the findings from the literature:

- avoiding as much as possible complex procedures

such as pulpotomy on very young patients;
- the incomplete removal of carious dentin tissue;
- the use of new technologies (ozone) for disinfection of carious dentine;
- the creation of a peripheral seal in the healthy tissue for bonding procedures with isolation of the operating field.

Once applied the ozone, it was possible to maintain a layer of dentin that could be called "ex-carious" which prevented the pulp exposure and subsequent pulpotomy. The use of this new technology is definitely more effective for the eradication of cariogenic bacteria than the protocol proposed by Magne. In the design of the cavity it is important to obtain as much as possible clean and supragingival margins in enamel, so as to have an excellent insulation of the operative field. Sometimes this is not possible, as in mesial or distal cavities the bottom of the cavity box ends in the dentin: the important thing is to have a cleaned margin and to properly isolate it with a dam. The finishing line on enamel margins allows maximum adhesion, and it is shown that the application of ozone does not affect the strength and adhesion of modern adhesive systems on enamel and dentin [Dukić et al., 2009; Magni et al., 2008; Pires et al., 2013].

Conclusion

It can be concluded that the proposed procedure has a high success rate if the dental pulp is not affected and uncovered, with rates comparable to those of pulpotomy, but with a considerable saving of healthy tissue and operating time. The technique can only be performed if there is no obvious pre-operative pulp exposure: the failures show that when the pulp is affected, success rates will drop dramatically. The four failures obtained after direct pulp capping are consistent with data in the literature that advise against its use [Smaïl-Faugeron et al., 2016]. The proposed protocol was effective and efficient in the treatment of deep carious lesions of deciduous teeeth.

The advantages of the new method are:
- reduced treatment time compared to pulpotomy;
- less destruction of tissue and less invasiveness;
- percentage of success at 12 months comparable pulpotomy;
- better sterilisation of carious dentin;
- more effective than partial removal of tooth decay without disinfection.

Further studies are needed to assess the success of the proposed treatment with a longer follow-up.

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