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Full Pulpotomy Addresses Deep Carious Lesions in a Simulated Deployed Military Dental Setting

by

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ABSTRACT

INTRODUCTION:

Tooth decay is one of the most prevalent chronic diseases in the world; adults aged 20-34 have 86% of their teeth with caries, missing due to caries, or filled. Moreover, the percentage of untreated decay nears 28%. Large carious lesions may become acutely symptomatic and require pulpal intervention (root canal). Factors such as access to care, cost, provider experience, resources/materials and treatment time may affect the outcome. A deployed soldier has an increased complexity of these factors. Full pulpotomy addresses the deep carious lesions and mitigates the challenge of endodontic care in a deployed setting. The purpose was to evaluate if a treatment protocol with bioceramics for full pulpotomy in patients with asymptomatic irreversible pulpitis/normal apical tissues provided short term prevention of pain (assessed during the first month) in a simulated deployed dental setting.

METHODS:

Three active-duty soldiers aged 18-25 were enrolled in the study. After informed consent, patients decided on treatment of full pulpotomy (VPT) or non-surgical root canal therapy (NSRCT). Full pulpotomy removed the diseased pulp tissue to the level of the orifices and restored with mineral trioxide aggregate (MTA) over the pulp stump, followed by glass ionomer and restored with a permanent restoration. Alternatively, NSRCT was completed with the provider's routine protocol. VPT post-op care included taking 4mg dexamethasone immediately postoperatively, at bedtime and the following morning. Patient completed a pain diary at 4hrs, 12hrs, 24hrs, 72hrs, 1 week and 1-month post operatively using the Defense and Veterans Pain Rating Scale 2.0.

RESULTS:

Mean pain score for VPT at 4, 12, 24, 72hrs, 1wk, and 1 month were 0, 0, 0, 0.5, 2.5, 0, respectively. Mean pain score for NSRCT at same time points were 2, 3, 1, 0, 0, 0, respectively. No patients required pain medications. All patients were satisfied with treatment.

CONCLUSIONS:

VPT showed minimal pain initially, but a late spike, while NSRCT showed initial pain, but a taper by 72 hours. All patients were asymptomatic at 1 month. No patients required rescue medications. VPT may be a valuable alternative for a deployed soldier who may not have access to higher echelons of care.

CLINICAL RELEVANCE:

VPT following the described protocol may be a valuable alternative for a deployed soldier who does not have access to specialist care. Treatment can be a definitive, field expedient treatment for pulpitis that has minimal chair time and is effective in a general dentist setting.

INTRODUCTION:

Tooth decay (caries) is one of the most prevalent chronic diseases in the world. Adults aged 20-34 years old have 85.58% of their teeth with caries, missing or restored. Moreover, the percentage of untreated decay in permanent teeth is 27.88% for adults aged 20-34 years old (1). Decay affects people of all ages and has various presentations from incipient decalcification of tooth enamel to gross caries that approximates the pulp chamber. Patients can have a wide range of signs and symptoms from extreme pain to minor sensitivity, to tooth discoloration, or lack of pain. The population of concern is asymptomatic patients with gross caries that extends into the pulp chamber. Barring non-restorable teeth, treatment options vary to include restorative treatment, vital pulp therapy (full pulpotomy), non-surgical root canal therapy (NSRCT) with a crown, extraction or no treatment. The validity of treatment is based upon removal of the infected tissue and success can be monitored by signs of infection, radiographic changes, color changes, or pain. Teeth with carious pulp exposures are traditionally diagnosed as irreversible pulpitis (asymptomatic) and prescribed root canal therapy. Unfortunately, the treatment decision can be driven by outside factors like time restraints, provider knowledge and skill, financial burdens or all of the above. In the upcoming age of vital pulp therapy and bioceramics, can a full pulpotomy with bioceramics be a valid and successful treatment option for patients who do not have the time or resources for NSRCT? And if so, what is the success of short term (1 month) VPT with full pulpotomy and bioceramics?

Dental caries, more commonly known as tooth decay, are caused by a breakdown of the tooth enamel. This breakdown is the result of bacteria on teeth that

metabolize foods and produce acid that destroys tooth enamel and results in tooth decay. Dental caries affects adults; 9 out of 10 adults over the age of 20 have some degree of tooth or root decay (2). Caries does not happen by chance; Keyes and Fitzgerald proposed that the three necessary criteria for caries to development is a susceptible host (saliva and teeth), microflora, and substrate (diet) (3). As diets are changing to include more sugar and fermentable carbohydrates, caries is expected to be a continued problem. Moreover, deployed soldiers commonly work 12-14 hour shifts and rely on energy drinks and sugary snacks to help them stay awake (60). Oral hygiene in a deployed setting or field environment is expected to decrease. If treatment is needed in a deployed environment, it is often limited and not ideal (60).

Caries can be classified clinically or radiographically, but often it is difficult to estimate the exact extent of decay until the removal has commenced through an operative procedure. Gugnani et al reviewed the International Caries Detection and Assessment System (ICDAS) in an attempt to standardize caries detection and assessment by recording caries along its continuum starting from its initiation stage as decalcification (4). Young et al streamlined the data, and with the work of the American Dental Association, created an easy-to-follow caries classification system that incorporates ICDAS (5). ICDAS visually categorizes caries based on dental hard tissue breakdown and starts with sound hard tissue with ICDAS 0 (no surface changes) to advanced carious lesion with ICDAS 6 (late cavitation/deep cavitation). Radiographic categorization is based on the extent of a radiolucency in the various structures of the tooth (enamel, dentin and pulp). The system begins with no radiolucency as an E0 and progress to a radiolucency that extends to the inner one-third of the dentin as D3, which

approximates the pulp space. The concern with large carious lesions (ICDAS 4, 5, 6 or D2 or D3) is the extension of bacteria and toxins into the dental pulp. Figure 1 demonstrates a large occlusal caries that enters the pulp horns.

Before delving into how bacteria affect the tooth, it is important to briefly define different health states of the pulp. Terms like vital pulp, necrotic, non-vital, infected, reversible pulpitis, irreversible pulpitis have all been used to describe the pulp status. All the following definitions were derived from the American Association of Endodontists (AAE) glossary of terms (7). A tooth is defined as vital when there is vascularization within the tooth. A healthy, vital tooth can become inflamed and be described as having pulpitis. Pulpitis is a clinical and histologic term denoting inflammation of the dental pulp; clinically described as reversible or irreversible and histologically described as acute, chronic or hyperplastic (7). An important subset based on extensive caries is asymptomatic irreversible pulpitis, which is a clinical diagnosis based on subjective and objective findings indicating that the vital inflamed pulp is incapable of healing (7).
Pulpal inflammation is commonly produced by caries, caries excavation, or trauma. Further irreversible inflammation results in a tooth becoming necrotic (non-vital), indicating death of the dental pulp. The pulp is usually nonresponsive to pulp testing. As mentioned before, bacteria are an important instigator for pulp inflammation.

Bacteria has been proposed as the source of pulpal infection by Kakehashi, Stanley and Fitzgerald (6). With a consistent food source, bacteria will keep dividing and can advance towards the pulp through the dentin tubules. Dentin tubules can act as an avenue for bacteria and are more numerous with a larger diameter closer to the pulp (13). The pulp is a, “Richly vascularized and innervated specialized connective tissue of

ectomesenchymal origin; contained in the central space of a tooth, surrounded by the dentin, with inductive, formative, nutritive, sensory and protective functions" (7). As bacteria and toxins enter the pulp tissue, an immunologic response takes place to help control the oncoming infection. The response creates local injury through inflammation. Figure 2 demonstrates how injury can be localized by a healthy pulp. Over time, the host defenses can be exhausted and the pulp tissue starts to necrose and eventually leads to total pulp necrosis. Bacteria can further use the necrotic issue as a food source and further divide and result in apical periodontitis (6, 8). One of the main goals of endodontic therapy is to remove the bacteria and to treat or prevent periapical pathology (9). "Endodontic treatment involves chemo-mechanical preparation of the root canal system to eliminate organic, inorganic and bacterial products and sealing of the radicular space with a biocompatible material (obturation). Root canal sealers are used in conjunction with the core filling material to establish an adequate three-dimensional seal and induce hard tissue formation in healing outcomes." Alternative treatments are also aimed at removing the bacteria and toxins from the pulp tissue. These treatments include vital pulp therapy (VPT): direct or indirect pulp cap, partial pulpotomy or full pulpotomy. Extraction is another alternative option that removes the entire tooth and associated bacteria. Full pulpotomy is the proposed treatment in this study.

According to the American Association of Endodontists (AAE), pulpotomy is the, "Removal of the coronal portion of a vital pulp as a means of preserving the vitality of the remaining radicular portion" (7). This preservation of vital pulp will allow the tooth to maintain its vitality, immune function, defense mechanisms, nutritive, and inductive properties that are important to the survival of the tooth (10). Swift, Trope and Ritter

proposed a set of requirements for successful vital pulp therapy including that the pulp is not inflamed, hemorrhage can be controlled, using a non-toxic capping material and sealing out bacteria (11). By removing the coronal portion of the pulp, the inflamed pulp tissue can be predictably removed (17). Some histological studies demonstrate that a cariously exposed vital pulp was not completely infected (12). Hemorrhage control can be an indication that the pulp tissue is more severely inflamed (12). In cases of severely inflamed pulp tissue, root canal therapy is considered the treatment of choice. Once the inflamed tissue is removed, a material must be placed to prevent microleakage. Cox and colleagues explained that the most important characteristic of a dental material with respect to its value in vital pulp therapy is its ability to prevent microleakage (14). Once sealed, healing can commence and hard tissue formation can progress. Provided the pulp remains healthy, this new dentin formation will continue at a normal pace, similar to formation in adjacent normal dentin areas (15). Besides addressing the biological concerns with pulp disease, VPT also addresses important economic factors as well.

Important economic factors include patient cost, procedure time and materials needed. Pulpotomy is a less invasive, cost-effective, simple, and less time consuming for the patients and doctors (18). Root canal therapy involves removing critical tooth structure around the pericervical portion of the tooth that can considerably weaken the tooth (19). Root canals often fail due to tooth fracture from the structural compromises (18, 19). Root canal therapy also removes the proprioceptive mechanism and losses an important damping effect, which are both important in protecting the tooth from excess force (25, 26). A pulpotomy will preserve the pericervical dentin, resulting in a significantly more amount of tooth structure remaining. A pulpotomy is considerably

more cost-effective than root canal therapy. According to the Defense Health Agency (DHA) Uniform Business Office (UBO), calendar year 2020 full outpatient rates for pulpotomy were one-fifth the cost of a molar root canal ($197.28 compared to $1,135.90, respectively) (20). In addition, it is recommended that a root canal treated tooth receive a crown, usually at an additional cost (DHA-UBO $1,190.82). Pulpotomy is a simpler procedure with less of an armamentarium. Root canal therapy is a challenging and technically demanding procedure that caries the risk of iatrogenic errors, file separation, or poor obturation that may affect the overall prognosis (18, 21, 22). In addition to being economical, pulpotomy has similar outcomes as root canal therapy.

Pulpotomy has been shown to be as effective as root canal therapy in prevention of pain and periapical pathology (18). Furthermore, survival and success rates are similar. According to Ng et al, a systematic review showing the survival of root canal treated teeth over 2-10 years ranged from 86-93% (23). Friedman et al showed the success of root canal therapy around 92-98% successful without a periapical lesion and around 74-86% successful with a periapical lesion (of those 91-97% remained functional) (24). Taha and Al-khatib demonstrated the survival of full pulpotomy at 6 months, 1 year, 2 years, and 4 years to be 98%, 97.4%, 93% and 83.8% respectively. Of those that failed, <50% were classified as endodontic failure (27). Aguilar et al showed success rates of full pulpotomy at <1 year, 1-2 years, 2-3 years and >3 years as 94%, 94.9%, 96.9%, and 99.3% respectively (12). Additionally, pulpotomy can progress to more invasive treatment if vital pulp therapy fails (16). At this time, pulpotomy would progress to root canal therapy and the success and survival would still be quite high, as demonstrated above. However, if root canal therapy fails, further

treatment can include retreatment, apical surgery or extraction. The success of these more invasive treatment can have reduced outcomes depending on the etiology of failure. Gorni and Gagliani reviewed the success rates of retreatment depending on the preoperative treatment factors and presence of an apical lesion (28). Teeth that had root canal morphology maintained and without an apical lesion, success was 91.6%, and with an apical lesion it was 83.8%. Teeth that had root canal morphology altered and without an apical lesion, success was 84.8%, and with an apical lesion it was 40% (28). Moreover, apical surgery shows similar success rates at 78% and survival at 95% (29). A recent article by Haxhia et al demonstrated similar survival of nonsurgical retreatment (90%, 86.8% and 85% at 2, 4, and 6 years respectively) and root end surgery (93.7%, 90.5% and 88% and 2, 4, and 6 years respectively) (30). As pulpotomy has been shown to be successful, the materials used play a factor in the outcome. There is not one standard of care method to complete a pulpotomy to yield predictable results; many materials have been proposed to be effective.

The main goals of the capping material should be to create and biocompatible and impervious seal to prevent bacterial leakage, arrest any further caries progression, and stimulate pulp cells to form new dentin (31). Pulpotomy can be completed with calcium hydroxide, glass ionomer cements, resin-based materials, and calcium silicate cements (bioceramics). Calcium hydroxide, glass ionomer cements, and resin based represent a lower range of success compared to bioceramics (10). Bioceramics are a relatively recent introduction to the dental field. Bioceramics are a group of bioactive calcium silicate-based materials that are biocompatible by nature with good physical and chemical properties used in endodontics as pulp capping or root end filling

materials (7). Bioceramics generally include alumina, zirconia, bioactive glass, coatings, composites, hydroxyapatite, and calcium phosphates (32). They generally have a high pH, are bioactive and biocompatible and provide an excellent seal throughout time (33). The high pH causes a liquefactive necrosis of the superficial pulp and helps remove any further inflamed tissue. This stimulates a minor irritation with an inflammatory response that, in the absence of bacteria, will heal with hard tissue (11). One of the most important factors needed for successful pulpotomy is a good coronal seal (27, 33). Marginal leakage of the restoration may lead to bacterial leakage into the remaining vital pulp tissue and cause necrosis and apical periodontitis (34). Murray and colleagues further demonstrated that the pulp's reparative activity happens more readily under a material that prevents bacterial microleakage (35). Mineral trioxide aggregate (MTA) forms an excellent seal that resists bacterial penetration (15, 33). The dentin formed adjacent to MTA showed a normal configuration and formed faster than with other materials (15). Also, MTAs ability to set in moisture makes it an attractive material for pulpotomy (15). Accordingly with all the properties of bioceramics, MTA is considered the optimal material for the use in pulpotomy of permanent teeth (36). Along with a good material, correct follow up is needed to ensure the health of the tooth.

Follow up with the patient includes clinical exam, radiographic exam and pain assessment via detailed logs. Clinical exam and sensibility testing helps evaluate pain responses, color changes, and restoration integrity. Radiographic exam helps evaluate periapical status, evidence of internal resorption or pulp canal obliteration, all providing evidence if a failure occurs (37). See Figure 3 for an immediate post op VPT completion that shows the various restorative layers. Orstavik et al determined a method to

evaluate the periapical status of a tooth called the periapical index (PAI) (38). The PAI provides an ordinal scale ranging from healthy (1) to severe periodontitis with exacerbating features (5). The value of the PAI score is that it allows teeth to be compared to each other in clinical trials and radiographic analyses (38). Pain is also an important factor on determining the outcome; Shallal-Ayzin et al determined that pain at three months significantly correlated with decreased outcomes. Therefore, pain during the first three months is predictive of poor treatment outcomes (39).

The follow up timeframe allows for treatment intervention as needed. With the correct diagnosis, treatment plan, treatment protocol and follow up, pulpotomy is a valid and realistic alternative to root canal therapy. Not only are the success and survival rates similar to that of root canal therapy, but the economic factors also play a large role in the final treatment plan. The goal of endodontic therapy is to treat or prevent apical periodontitis, and if this can be complete in a more economical and less invasive manner, it can become the first line treatment in the future (9). The purpose of this study was to evaluate if a treatment protocol with bioceramics for full pulpotomy in patients with asymptomatic irreversible pulpitis/normal apical tissues provided short term prevention of pain (assessed during the first month) in a simulated deployed dental setting.

MATERIALS AND METHODS:

This observational prospective cohort study was carried out in the specialty clinic of the US Army advanced dental education in endodontics at Ft. Gordon, GA. Three

active-duty soldiers aged 18-64 were enrolled in the study and received treatment by a single provider (I.P.) between March 2022 and February 2023. All treatment was completed with verbal and written informed consent. The study was approved by The Naval Medical Center Portsmouth IRB office (IRB number DDEAMC.2022.0034).

Patients were screened at the dental treatment facilities for large cavities that approximated the pulp chamber (ICDAS 4, 5 or 6 and radiographically D2 or D3) or if they had a history of restorative treatment with a carious pulp exposure. Pulp sensibility testing was completed with Endo Ice (1,1,1,2 tetrafluoroethane) (Coltène/Whaledent, Cuyahoga Falls, Ohio), Electronic Pulp Tester Vitality Scanner 2006 (Kerr, Brea, CA), bite with tooth slooth (Professional Results, Inc., Laguna Niguel, CA), percussion with the blunt end of a mirror handle, palpation with digital pressure around the apices, mobility with the blunt end of 2 instruments, and probing with UNC-15 probe. Bitewing radiographs taken to estimate the restorability and extension of caries and two periapical radiographs taken to assess the periradicular status of the tooth. Patients were eligible for inclusion in the study if they had a pulpal diagnosis of asymptomatic irreversible pulpitis as defined as extension of caries into the pulp with normal response to cold or slight elevated response to cold that quickly returns to normal. Periapical diagnosis of normal apical tissues as shown by no pain to percussion or palpation and no rarefactions on the radiographs. Other inclusion criteria included: Large carious lesion close to the pulp, history of carious pulp exposure, ability to follow up with patient, patient accepting treatment plan, and patient freely elected to be included in the study. Exclusion criteria included the presence of pulp stones, inability to control hemorrhage, periapical radiolucency, pregnancy or inability to follow up with the patients for the

designated time frame. Patients were presented the treatment options of no treatment, extraction, non-surgical root canal therapy (NSRCT) or vital pulp therapy (VPT)-full pulpotomy. If patient elects for either VPT or NSRCT, they were presented with the option to be included in the study. Informed consent was obtained with the DHA informed consent form, which includes, but is not limited to, institution name, title of the proposed research, principal investigator, key information about the study, purpose and duration of the research, screening process, what happens if patient agrees to be include in the research, risks, benefits and alternatives of full pulpotomy and non-surgical root canal therapy, associated information privacy, HIPAA authorization and how data was utilized. All informed consent documents were stored in the patient's chart and locked in a Kardex after hours. If the patient elects to be included in the study, the appropriate paperwork was be completed and follow up instructions were given (see last section for detailed description). At any time, patient could request to be withdrawn from the study and treatment would be completed under routine treatment conditions.

Demographics were recorded to include tooth type, gender, age, and pre-operative pain level. Treatment protocol for VPT: 20% topical benzocaine was placed on mucosa prior to local anesthesia injection. Patients were anesthetized with 2% lidocaine with 1:100k epinephrine (Henry Schein, Melville, NY) or 4% septocaine with 1:100k epinephrine (Henry Schein, Melville, NY) until profound pulpal anesthesia was achieved, not to exceed maximum recommended doses of 300mg lidocaine or 500mg septocaine. Isolation was achieved with a rubber dam. Caries excavation was completed to sound enamel and dentin. A new sterile bur was placed on the handpiece and the pulp chamber was conservatively accessed and coronal pulp amputated with sterile fine diamond bur

with copious water to the level of the orifice. Pulp chamber was disinfected with 0.5-1.25% NaOCl (Clorox, Oakland, CA). Hemostasis was achieved with a NaOCl soaked moist cotton pellet. Verified healthy pulp tissue by direct visualization and lack of prolonged hemorrhage. If hemostasis was not achieved within 10 minutes, patient was notified and NSRCT was completed. For posterior teeth, mineral trioxide aggregate (ProRoot® MTA) (DENTSPLY Tulsa Dental Specialties, Johnson City, TN) was placed over healthy pulp tissue and covered with glass ionomer cement (Vitrebond Plus™, 3M ESPE, St.Paul, MN). For anterior teeth, a non-staining Neo MTA 2 (NuSmile Ltd., Houston, TX) was used in the same manner as described for MTA. Access cavity was restored with permanent restoration of composite according to manufacturers recommended instructions for use. If indicated, crown preparation and placement could commence. Full pulpotomy was intended as definitive treatment. Patient was given 4mg dexamethasone tablet immediately postoperative. Patient followed up with a 4mg dose before bed and immediately when they woke up. Rescue medication included 800mg ibuprofen tabs taken up to 3 times a day not to exceed 2,400mg/day and 325mg acetaminophen taken as needed not to exceed 3,200mg/day. The dental provider was available to see the patient if emergency care was warranted. Also, emergency room support was available in severe cases involving impaired breathing, swallowing or diffuse swelling. If the patient elected NSRCT, a modified crown down technique utilizing 5.25% NaOCl, removal of the smear layer with 17% EDTA, and a final rinse with 5.25% NaOCl. Obturation was completed with gutta percha and Endosequence BC Sealer (Brasseler USA, Savannah, GA). Restoration was completed in a similar manner as full pulpotomy.

Follow up schedule included a pain diary survey completed through Google Forms (Google, Inc., Mountain View, CA) at 4hrs, 12hrs, 24hrs, 72hrs and 1 week. The survey was accessible through a QR code on a business card that was handed out at the end of the appointment. The patient was also handed a paper copy if they did not have access to the internet. The card included the date, time and procedure completed for reference (no PHI nor PII was associated or collected with the card/survey). The survey collected the procedure completed (NSRCT or VPT), date and time of treatment, selection of the follow up interval (4, 12, 24, 72hrs or 1 week), level of pain on a 0-10 scale according to Defense and Veterans Pain Rating Scale (DVPRS 2.0), and if any pain medications were taken. See figure 4 for DVPRS 2.0. Satisfaction with treatment was assessed with a "yes" or "no" at the end of the 1-week time period. Patients returned in one month to repeat the initial pulp sensibility testing and radiographs. Radiographic evaluation used the PAI scoring system to assess periapical status. Success was defined by absence of signs and symptoms, absence of radiographic pathology and intact permanent restoration. Survey can be accessed with the following link: https://docs.google.com/forms/d/e/1FAIpQLSfDFEI0c8CAYcYU9OLiSd-LzRGeuvz55b9IdOlbZ7FXdukXWw/viewform

RESULTS:

Following clinical treatment, all three enrollees were available for follow up. The gender, age, initial pain scores and tooth type are presented in Table 1. There was no difference in the gender, age or initial pain scores. NSRCT and VPT did vary by tooth

type; NSCRT treatment was solely on molars. VPT group had twice the number of participants as NSRCT.

Post op pain values are presented in Table 2. Mean pain score for VPT at 4, 12, 24, 72hrs, 1wk, and 1 month were 0, 0, 0, 0.5, 2.5, 0, respectively. Mean pain score for NSRCT at same time points were 2, 3, 1, 0, 0, 0, respectively. VPT demonstrated no pain initially, but a slight increase at 1wk. NSRCT demonstrated pain initially, but dissipated by 72hrs. All patients were asymptomatic at one month. Long term outcomes were not evaluated during this study.

Satisfaction with treatment and pain meds used are presented in Tables 3 and 4, respectively. All patients were satisfied with treatment. No patients required post op pain medication.

DISCUSSION:

The purpose of this study was to evaluate if a treatment protocol with bioceramics for full pulpotomy in patients with asymptomatic irreversible pulpitis/normal apical tissues provided short term prevention of pain (assessed during the first month) in a simulated deployed dental setting. Specialty care, especially for deployed soldiers, may be difficult to obtain based on location or resource availability. Factors such as access to care, cost, provider experience, resources/materials and treatment time may affect the outcome of various treatments. A deployed soldier has an increased complexity of these factors. Full pulpotomy addresses the deep carious lesions and mitigates the challenge of endodontic care in a deployed setting.

Pain was the assessment marker of choice for this specific study. According to IASP, pain is, “An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage.” Pain is a unique personal experience and is influenced by biological, psychological and social factors and may lead several adverse effects on function, social and psychological well-being (41). Pain has the ability to affect a person’s actions and behaviors. The DVPRS 2.0 (Figure 4) was used to assess pain due to its ability to categorize pain on a multi-faceted level. This scale considers the visual aspect with facial expressions, a graded color coding that correlates with severity, and a verbal description of pain that the patient can match with their feelings. Patients enrolled in this study were all asymptomatic by design. The goal was to simulate patients/soldiers that develop large caries while overseas, deployed with large caries or don’t have access to regular dental care. Caries that may become an acute dental problem within twelve months are classified as emergent dental conditions that need treatment. Large caries, in a military sense, makes the patient non-deployable and is generally treated on an as soon as possible basis. The patients enrolled in this study all had large caries that extended into the pulp chamber. The goal in providing treatment was to prevent a dental emergency that may happen in the next twelve months. So, is conservative treatment with VPT enough to address the clinical situation and prevent the emergent condition from happening? It is important to reiterate the validity of VPT and how it can address the inflamed pulp tissue by selectively removing the inflammation, placing a biocompatible filling material, and providing a permanent restoration (42). Other treatment options are NSRCT or extraction.

NSRCT and extraction are treatments with known post op pain. A study by Gotler demonstrated post op pain for NSRCT with vital pulps at 6 hrs and 18 hours where 63.8% patients had a mean pain score of 2.46/5 at 6 hours and 51.8% patients had a mean pain score of 2.00/5 at 18 hours (43). A study by Al-Khateeb demonstrated post op pain for a simple tooth extraction to be 81.8% the evening of the extraction, 68.1% at day 1, 47.8% at day 3, 26.6 % at day 5, and 22% at day 7 (44). A study by Shallal-Ayzin demonstrated 38% post op pain for VPT at 24-hr, 22% at 1 week and 12% at 3-month (39). A study by Rousseau compared intra-operative pain levels for restorative, NSRCT and extraction. It was determined that 4.22% had pain during operative, 7.73% had pain during NSRCT and 23.98% had pain during extraction (45). This study further bolsters the uncomfortable nature of dental procedures and how more invasive treatment like NSRCT or extraction can leave the patient in more pain than conservative treatments like VPT.

In this study, post op pain was evaluated for both NSRCT and VPT, assuming that the least post op pain would allow the patient to incorporate back to their daily habits more seamlessly. Our data clearly shows that VPT may be a valuable alternative to NSRCT by using the protocol described. See figure 5 for a comparison of VPT and NSRCT for the first month. VPT had no pain initially, but an increase to a mean of 0.5 at 72hrs and 2.5 at 1 week. All patients were asymptomatic by 1 month. One thought behind the initial lack of pain with VPT is due to its more conservative nature. There is minimal manipulation of the tissues, high speed diamond burs create a clean wound and help with hemostasis, and healthy pulp tissue remains to help fight inflammation. Another factor may have been dexamethasone; dexamethasone is a glucocorticoid that has a robust

effect on the body. It inhibits phospholipase A2 which prevents the formation of arachidonic acid derivatives and many inflammatory mediators like prostaglandins and leukotrienes. It has the ability to reduce inflammation by inhibiting pro-inflammatory signals and promoting anti-inflammatory signals. There is a decreased vasodilation and permeability of capillaries and decreased leukocyte migration to sites of inflammation (46, 47, 48). All these effects essentially downregulate the immune system and can potentially allow the pulp to heal more promptly after the severing of the pulp tissue; the reduced inflammatory response won't cause the pulp to succumb to the trauma that was caused. The concern is if bacteria gain entry into the pulp tissue; the pulp and diminished immune response may not be able to clear the bacteria and a pulp infection may ensue. Shah demonstrated that dexamethasone significantly reduced pain and swelling postoperatively during microsurgery compared to a placebo group (47). A concern with dexamethasone is its ability to cross the placenta and have detrimental effects to the fetus. A study by Cheng showed the risks of embryonic skeletogenesis and dangers to skeletal progenitor cells during development (49). The potential teratogenic effects were the reasons why pregnancy was part of the exclusion factors.

NSRCT demonstrated minimal initial pain (mean 2 at 4hrs, 3 at 12 hrs and 1 at 24 hrs), but no pain for the rest of the study. The pain may be attributed to the increased complexity and manipulation of tissues required for a root canal. Injections into the pterygomandibular space may cause reportable post op pain. Root canals may result in manipulation of the periapical tissues due to overinstrumentation, packing debris into tissues or extrusion of foreign material (gutta percha or sealer). Root canals also take

longer where the patient may experience muscle fatigue and discomfort in their temporomandibular joint.

Although pain is just one of the many factors associated with success, it is often the one that affects patients the most. The fact that VPT has lower pain than NSRCT can be beneficial in the deployed or rural setting. It is a quicker and simpler treatment that appears to have lower post op pain. This lower post op pain can allow the patient to return to their daily lives quicker and have less morbidity.

Post op medication evaluated a patient's perception of pain; the goal was to determine if the pain they experienced was severe enough that they needed analgesics. Lastly, overall satisfaction was to assess if the patient was happy with treatment, including treatment time, positioning, workflow, and post op pain levels. It appears that with our population, either treatment option was acceptable to the patient. However, for a population that may not be able to handle the longer treatment times, or being open or laying back, shorter appointments may be valuable.

Another goal of the study was to outline a specific protocol that can be used in a general dentist setting (I.e., deployed or rural). The first step in the protocol is adequate case selection. The focus of this study was asymptomatic irreversible pulpitis with normal apical tissues which was diagnosed through clinical and radiographic evaluation. Patients were not eligible for the study if they had a history of symptoms, were pregnant, had hyperemic pulps, pulp stones or radiographic pathology. Although studies show that VPT on patients with these factors are successful (12, 27,42), we wanted to reduce the number of variables that could affect the outcome. Hyperemic pulp is a clinical indication of inflammation; inability to control heme may demonstrate that the inflammation spreads to

a level that cannot be removed by full pulpotomy (12). Pulp stones and radiographic pathology may be indicators of inflammatory changes in the pulp (50).

After informed consent, treatment commenced. The protocol outlined was one that could be applied to a general dentist setting (i.e. deployed or rural). The concept was using materials that are commonly available, like rubber dams, variety or burs, loupe magnification, NaOCl and a bioceramic material (although not routinely used, it is good to stock bioceramics in case of pulp capping or pulpotomies). The protocol was designed around the AAE position statement on vital pulp therapy (51). Treatment was designed to use loupes commonly found in a general dentist setting (2.5-4.0x). Although this magnification is lower than what is used with the dental operating microscope, it should still allow adequate visualization of the pulp tissue and assessment of the pulp stump. The provider in this study used 4.0x magnification. Treatment started routinely with local anesthetic until the patient was profoundly numb. Rubber dam isolation was a requirement for any restorative procedure that may result in pulpal intervention, especially when the pulp tissue was exposed. Rubber dam is known to improve infection control and treatment efficacy and protects patients (52). Next, complete removal of all circumferential caries was completed without entering the pulp chamber. Burs were replaced with new, sterile diamond burs to enter the pulp chamber and remove the inflamed tissue to the level of the orifice. This was designed to create the smallest wound possible, increase the space for restorative material and allow adequate hemostasis. Hemostasis was completed with 1.5% NaOCl with sterile cotton pellets. At this point, the next decision was made; if hemostasis could not be achieved, NSRCT was completed. The hemorrhage was assumed to indicate that the pulp tissue is more inflamed than what was initially

presumed. If hemostasis was achieved, MTA was placed over the pulp stumps filling the pulp chamber.

MTA is preferred based on its excellent biocompatibility, sealing ability and ability to promote hard tissue formation (hydroxyapatite) (36, 53). The challenges with MTA is its difficult handling properties and potential for staining (53). Placement was completed using an Endo Gun (Medidenta, Las Vegas, NV) and gently packed over the pulp stump and floor with an amalgam condenser (selected due to its common availability in a general dentist restorative set up). The importance of placing a light cured RMGI is threefold. First, it chemically bonds to the tooth through its action of polyacrylic acid interacting with calcium ions in the dentin. Fluoride and strontium are also released which can help protect adjacent dentin (54). Second, placement does not require an etch with polyacrylic acid, although it can increase the chemical bond, it is not required. Etching would wash out the MTA. Lastly, it creates a protective layer that allows etch and rinse of various bonding systems. Final step was immediate placement of a permanent restorative material. All these steps were deliberately selected via evidence-based techniques to increase the chance of success with VPT.

A few drawbacks were identified throughout the study. First was through patient selection criteria and enrollment. Patient population was from a single location with a single referring clinic. This clinic typically focused care on young soldiers in the age range of 18-30. Although this is the target sample that we wanted to focus on, it does not represent the entire Army population. The best-case scenario would be a randomized controlled, multi-center study comparing VPT, NSRCT and extraction. Second, patient enrollment was extremely low. Only three patients were included in the study. Although

100% of those patients were available for follow up, two other patients could not be included for the following reasons: one patient was dismissed due to inability to control hemorrhage and one patient self-disenrolled from the study 1 hour after termination of treatment. A larger sample size is a must. Prior to initiation of the study, a power analysis was performed. With a power of 0.80, alpha of 0.05, beta at 0.20, and estimated effect size of 1, a sample size of 16 patients per group for a total of 32 patients was estimated. Due to the low enrollment, statistics were not evaluated due to the high probability of error. If statistics were going to be calculated, a Student's t-test of the mean pain score at 4, 12, 24, 72, 1 week and 1 month for VPT vs. NSRCT would be calculated. Methods to mitigate this low enrollment would be to modify the inclusion criteria to allow symptomatic patients with the diagnosis of reversible pulpitis to join the study. Numerous patients screened had large caries with a recent history of pain, although asymptomatic in the chair. Patients with spontaneous pain, nocturnal pain, lingering pain or throbbing would not be included due to chance of irreversible pulpitis (evidence of bacteria in the pulp and areas of necrosis (55)). Another method to increase the enrollment would be to introduce more providers to complete treatment. Although this would complicate the study because it would introduce more provider variability and require a calibration session, it would increase the amount of patients that could be seen at various clinics across the Army. Future studies should be randomized control studies with larger sample sizes. Also, studies should include qualitative data to be able to compare the types of pain the patients are having.

Significance/military relevance:

Oral disease and conditions can cause severe pain and dysfunction that interferes with a soldier's ability to eat, communicate, sleep or concentrate and can become life-threatening if not treated (56). Furthermore, these dental emergencies are referred to as Dental Disease Non-battle Injuries (D-DNBI) and can be defined as any unscheduled oral or craniofacial issue perceived by the soldier to be a problem, which causes them to seek help (57). According to Simecek et al, of the fifteen most frequent D-DNBI encounters during Operations Iraqi Freedom and Enduring Freedom, nine out of the fifteen involved caries, pulpitis, pulp necrosis, or apical periodontitis, all of which are addressed by some level of pulpal therapy. Dental caries ranked the highest at 10% while periapical abscess ranked the lowest at 2.21% (58). Further cost analysis by Colthirst et al revealed that the cost of emergency dental care over a 24-month period was $44M, or $1.8M per month (59). Further breakdown showed cost per soldier for three days of care to be just over $1,000. This data suggests that dental emergencies cost valuable time, money and resources and the majority are associated with the dental pulp and endodontics. In conclusion, VPT is a field expedient treatment for pulpitis that has minimal chair time, is effective in a general dentist setting and may prevent D-DNBI.

VPT allows conservative treatment of inflamed pulp tissue as a more economical and less technique-sensitive option. Pulpotomy can achieve similar success and survival without the burden of 1-2 multi-hour NSRCT appointments and 1-2 multi hour crown appointments. Pulpotomy leaves healthy pulp tissue that can potentially provide immune protection for the tooth, allows proprioception and helps maintain the surrounding

periodontium. The sequela of pulpotomy can be addressed with further care of root canal therapy and maintain high success rates.

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The authors deny any conflicts of interest related to this study.

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Figure 1. Periapical radiograph showing deep primary caries

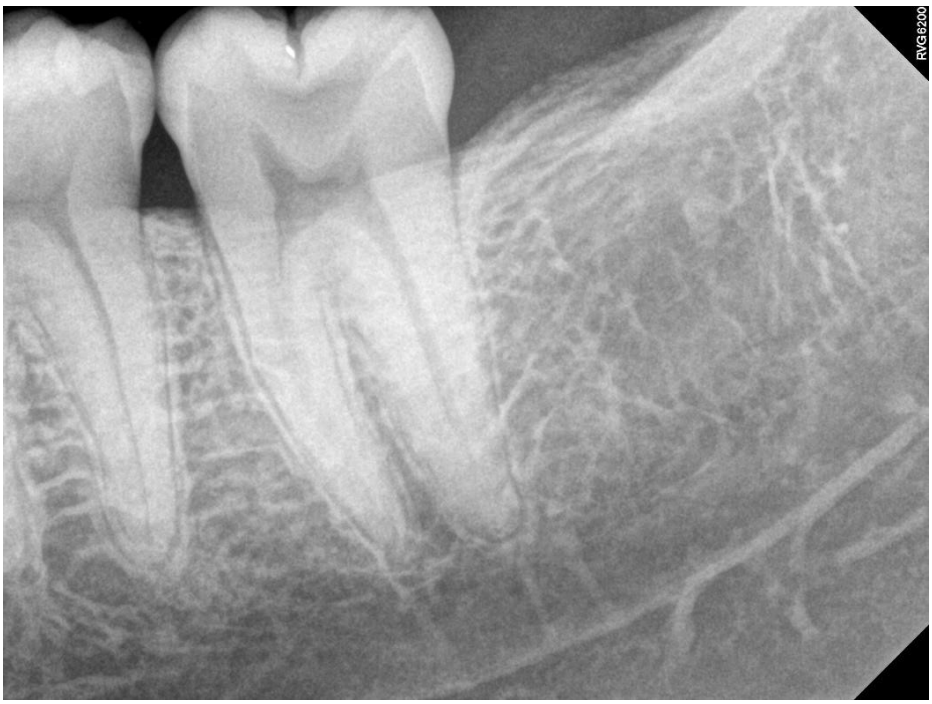

Figure 2. Intraoperative photo showing localized extent of inflammation

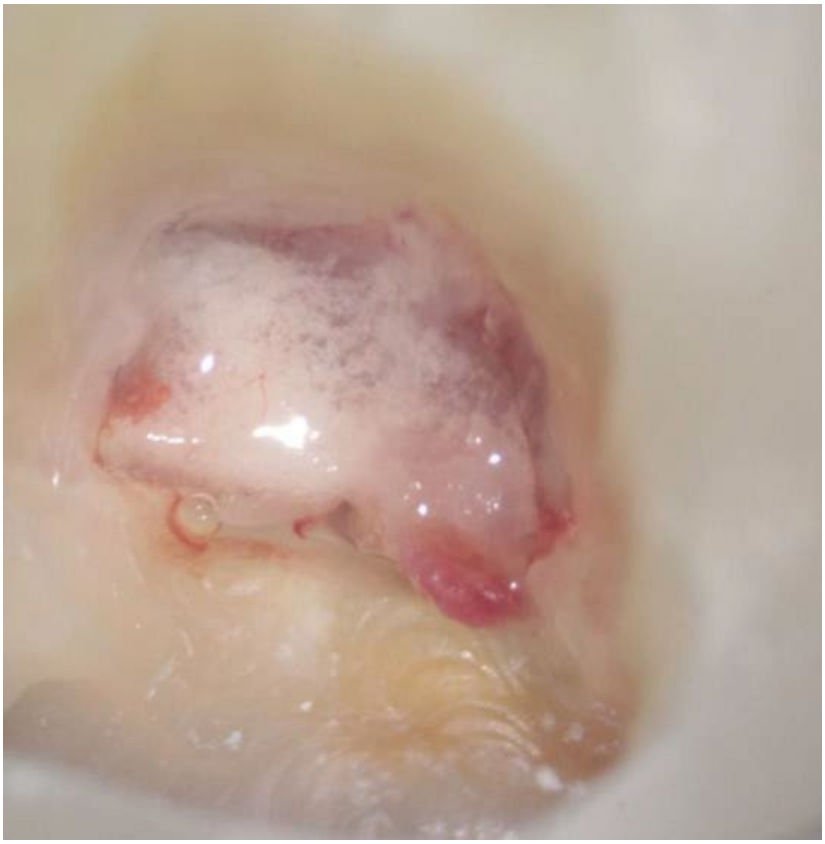

Figure 3. Periapical radiograph showing completed VPT with MTA, Vitrebond and final restoration.

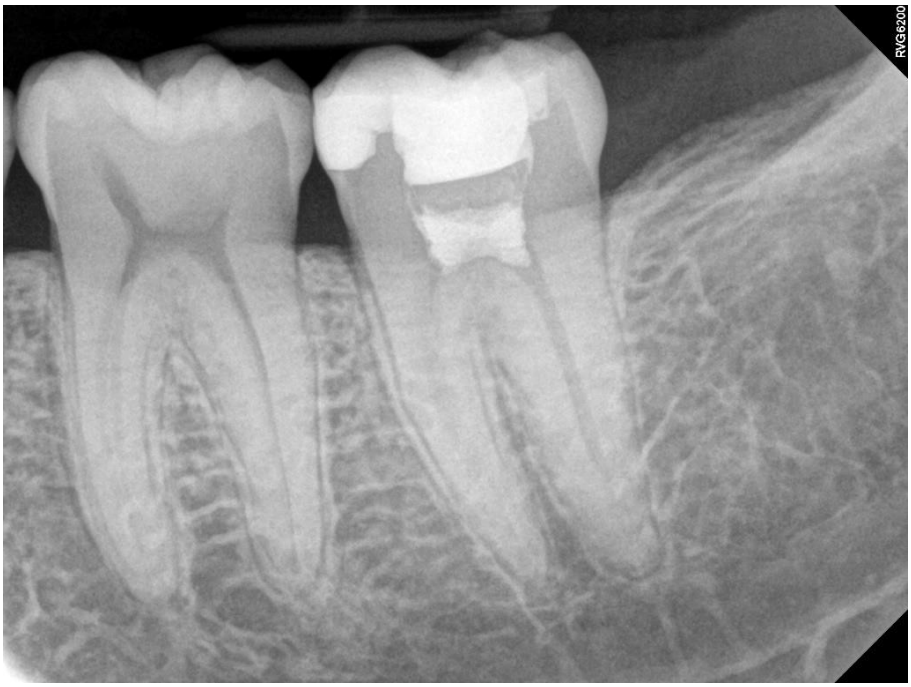

Figure 4. Defense and Veterans Pain Rating Scale 2.0 (DVPRS 2.0)

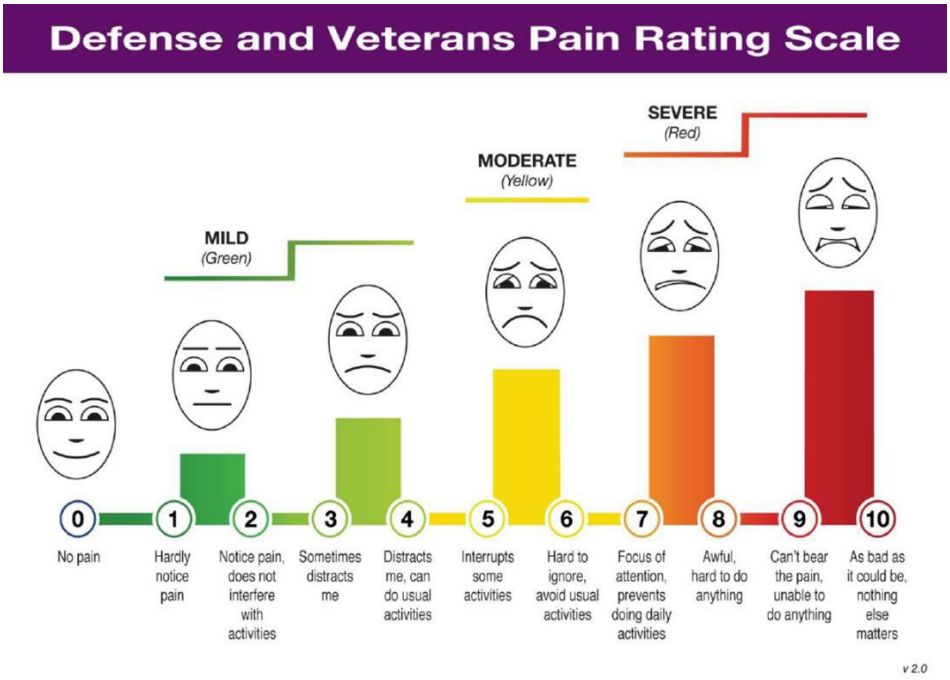

Figure 5. Mean DVPRS 2.0 pain scores of full pulpotomy vs. non-surgical root canal therapy

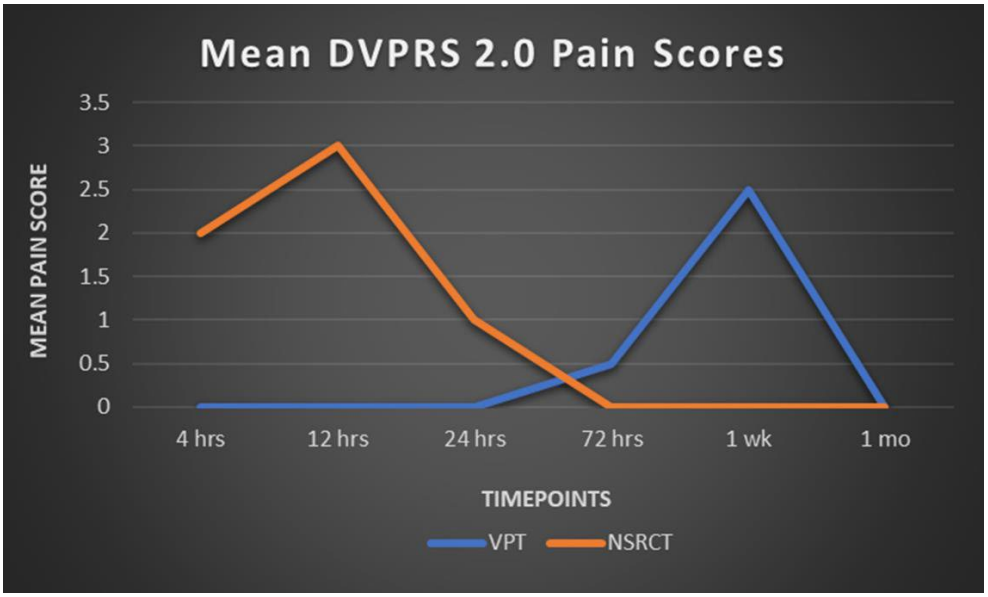

Table 1. Patient demographics

	Vital Pulp Therapy	*NSRCT*
Total Subjects	2	1
Total Analyzed	2	1
Gender	M 100% F 0%	M 100% F 0%
Age (mean)	22	22
Initial Pain (mean)	0	0
Tooth type	Molar 50% Premolar 50%	Molar 100%

Table 2. Mean post op pain (DVPRS 2.0)

	Vital Pulp Therapy	*NSRCT*
4 hrs	0	2
12 hrs	0	3
24 hrs	0	1
72 hrs	0.5	0
1 week	2.5	0
1 month	0	0

Table 3. Satisfaction with treatment

	Vital Pulp Therapy	*NSRCT*
Yes (%)	100	100
No (%)	0	0

Table 4. Rescue pain medications required

	Vital Pulp Therapy	*NSRCT*
Yes (%)	0	0
No (%)	100	100