AN EVALUATION OF THE GOW-GATES AND VAZIRANI-AKINOSI INJECTIONS IN PATIENTS WITH SYMPTOMATIC IRREVERSIBLE PULPITIS

A Thesis
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The purpose of this study was to evaluate the degree of pulpal anesthesia obtained with the Gow-Gates and Vazirani-Akinosi techniques using 3.6 mL of 2% lidocaine with 1:100,000 epinephrine, in patients presenting with symptomatic irreversible pulpitis. One hundred and twenty emergency patients (diagnosed with symptomatic irreversible pulpitis of a mandibular posterior tooth) received either a Gow-Gates or Vazirani-Akinosi injection to block the inferior alveolar nerve before endodontic access. Block success of the injection was defined as subjective lip numbness. Pulpal anesthetic success of the injection was defined as no pain or mild pain upon endodontic access or instrumentation as measured on a 170 mm visual analog scale. The results showed that block success was obtained in 92% of subjects receiving the Gow-Gates injection and 63% of subjects receiving the Vazirani-Akinosi injection. Among the Gow-Gates subjects, successful pulpal anesthesia was obtained 35% of the time. Among Vazirani-Akinosi subjects, successful pulpal anesthesia was obtained 16% of the time. Neither the Gow-Gates or Vazirani-Akinosi injections provided adequate pulpal anesthetic success rates. Both injections would require supplemental anesthesia. We would not recommend the Vazirani-Akinosi injection for routine endodontic treatment.
DEDICATION

To my dad, who taught me that all doctors are scientists.

To my mom, whose brains, beauty, and strength inspire.

To my teachers who taught me to write well and think big.

To my husband Ben whose unending love, support, and boundless energy sustain my curiosity and courage.

In memory of Gpa and Dede, both scientists, who I know are so proud of me.
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To Emily, Brett, and Shayne: Thank you for your tenacious recruitment of study patients, introduction to superb Mexican food, and being game for anything – including sneaking into Fenway in a sausage cart.

To my sister Katrina, who knows me (and Microsoft Office) better than anyone. You are my forever friend.
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CHAPTER 1
INTRODUCTION

The Inferior Alveolar Nerve Block

Varying the volume of 2% lidocaine with 1:100,000 epinephrine, 1.8 mL versus 3.6 mL, showed no significant difference between the two volumes when tested for successful pulpal anesthesia in healthy, asymptomatic teeth (1). Dagher et al. found that varying the concentration of epinephrine in a 1.8 mL dose of 2% lidocaine solution (1:50,000, 1:80,000, and 1:100,000) also revealed no significant differences in success and failure of the inferior alveolar nerve block (2). Wali et al. concurred that the anesthetic efficacy of 1.8 mL or 3.6 mL of 2% lidocaine with 1:50,000 does not result in more successful pulpal anesthesia when compared with the standard 1.8 mL 2% lidocaine with 1:100,000 epinephrine for an inferior alveolar nerve block (3). Examining both volume and concentration, Vreeland et al. found 1.8 mL of 2% lidocaine 1:100,000 epinephrine, 3.6 mL of 2% lidocaine with 1:200,000 epinephrine, and 1.8 mL of 4% lidocaine 1:100,000 epinephrine to have no significant differences in anesthetic success or failure (4).
Yared and Dagher’s study examined varied epinephrine concentrations (1:50,000, 1:80,000, and 1:100,000) in 1.8 mL of 2% lidocaine and supported Vreeland’s findings. No significant difference in anesthetic success and failure were found in their test span of 50 minutes among the mandibular first molar, first premolar and lateral tooth (5). This indicates that a higher concentration of epinephrine does not affect the incidence of pulpal anesthesia utilizing the inferior alveolar nerve block.

In contrast to Nusstein’s study, Yared and Dagher evaluated 3.6 mL versus 1.8 mL of 2% lidocaine with either 1:50,000, 1:80,000, or 1:100,000 epinephrine concentrations and found that among thirty adult subjects, the volume of solution did influence the degree of anesthesia in that the incidence of anesthesia was greater when the solutions were doubled in volume (5). The same group of subjects studied in their evaluation of 1.8 mL of 2% lidocaine with varied epinephrine concentrations, were included in this study. The average age of the subjects was 32 years. Subjects were in good health and were not taking any medications that would alter their perception of pain. Mandibular right and left sides were tested in equal number utilizing the first molar, first premolar, and lateral incisor as test teeth. The contralateral canine was used as the control to ensure proper function of the pulp tester and adequate response of the subject during the experiment. Clinical examination of the dentition ensured all teeth to be tested were free of caries, large restorations, periodontal disease, history of trauma, or sensitivity. A repeated measures design was utilized such that each subject randomly received each anesthetic solution on three successive appointments at least one week apart. Baseline pulp testing was performed on all four test teeth, after which the inferior alveolar block was administered as described by Malamed (6). All of the pre-injection and post-injection
tests were done by a trained evaluator who was blinded to the injected solutions. At 1 minute post-injection, the first molar was pulp tested and alveolar mucosal sticks performed. At 2 minutes, the first premolar and lateral incisor were tested. At 3 minutes the control canine was tested and the subject was asked if their lip and tongue were numb. The cycle was repeated every 3 minutes and stopped at 50 minutes post-injection. Results from this study were retrospectively compared with the results from their previous 1.8 mL 2% lidocaine 1:50,000, 1:80,000, 1:100,000 study. Though no significant differences were found among the three various solutions using the 3.6 mL volume (a finding that supports the authors’ evaluation of the 1.8 mL volume), Yared and Dagher noted a generally higher level of anesthetic success and lower levels of anesthetic failure, slow onset anesthesia, and anesthesia of short duration in subjects receiving the higher volume of anesthetic. It must be noted that none of these changes were statistically significant. Doubling the anesthetic volume to 3.6 mL resulted in continuous anesthesia for the tested teeth as the incidence of non-continuous anesthesia dropped to 0 among all three evaluated solutions. The authors concede that their findings disagreed with Vreeland’s findings due to differences in methodology and materials. Yared and Dagher’s study compared their findings using 3.6 mL of solution to a retrospective study that used 1.8 mL volumes whereas Vreeland’s study (4) directly compared 1.8 mL and 3.6 mL volumes of 2% lidocaine 1:100,000. Additionally, the two studies differed regarding the amount of epinephrine contained within their anesthetic solutions. Yared and Dagher’s study compared 2% lidocaine with 1:50,000, 1:80,000, and 1:100,000 whereas Vreeland’s study utilized 2% lidocaine with 1:100,000, 1:200,000 and 4% lidocaine with 1:100,000 epinephrine.
Hinkley et al. evaluated two commonly used anesthetic solutions, 4% prilocaine with 1:200,000 epinephrine and 2% mepivacaine with 1:20,000 levonordefrin, against 2% lidocaine with 1:100,000 epinephrine for the inferior alveolar block and showed no significant difference in onset, success, failure or incidence among the three tested solutions in a 1.8 mL quantity (7). McLean et al. evaluated other anesthetic solutions such as 4% prilocaine and 3% mepivacaine with 2% lidocaine (1:100,000 epinephrine) and revealed no significant difference in onset, success, or failure among the three solutions (8). Furthermore, Mikesell et al. investigated the comparison of 1.8 mL 4% articaine 1:100,000 epinephrine and 1.8 mL 2% lidocaine for the inferior alveolar nerve block and revealed no significant difference among the two solutions (9), despite articaine’s reputation of providing improved local anesthetic success (10).

Investigation of a possible synergistic effect of carbon dioxide with local anesthetics (11) resulted in Chaney et al.’s study using lidocaine hydrocarbonate compared to lidocaine hydrochloride for the inferior alveolar block (12). Results showed that 2.2% lidocaine hydrocarbonate with 1:100,000 epinephrine and 2% lidocaine hydrochloride with 1:100,000 epinephrine show no significant differences in providing a successful inferior alveolar block. Notably, 2.2% lidocaine hydrocarbonate with no epinephrine was not as effective as the other other solution in providing pulpal anesthesia (12). Ridenour et al. examined the effect of supplementing 2% lidocaine with 1:100,000 epinephrine with hyaluronidase, an enzyme that permits a wider spread of injected fluids, to evaluate its potential enhancement of the inferior alveolar nerve block’s pulpal anesthetic success (13). Results revealed no significant increase in the incidence of pulpal
anesthesia, though the hyaluronidase buffered solution did produce a significant increase in postoperative pain and trismus (13).

Whitcomb et al. examined the effect of buffered 2% lidocaine with 1:100,000 epinephrine, using a sodium bicarbonate formulation (14). An electric pulp tester was used in 4 minute cycles to determine pulpal anesthetic success in the first and second molars, premolars, lateral and central incisors. The objective of the study was to determine whether buffering the anesthetic solution to a higher pH, 7.50 versus the unbuffered 6.40, would result in increased pulpal anesthesia and reduced pain of injection. The authors found no statistical difference in pain of injection, onset, or anesthetic success between unbuffered 2% lidocaine with 1:100,000 epinephrine and buffered 2% lidocaine with 1:100,000 epinephrine for the inferior alveolar nerve block.

Willett et al. evaluated the efficacy of diphenhydramine as an anesthetic solution for the inferior alveolar nerve block (15). The study found its use as a local anesthetic was irritating upon injection as well as post-injection. The 1% diphenhydramine solution resulted in low levels of pulpal anesthesia: 10% anesthetic success for 2nd molars and 0% anesthetic success for the first molar, premolars, lateral incisor, and central incisor. Significantly higher levels of pulpal anesthesia were noted with 1.8 mL of 2% lidocaine with 1:100,000 epinephrine.

Goodman et al. studied the efficacy of a lidocaine/meperidine solution for an inferior alveolar nerve block (16). The authors compared pulpal anesthetic success of 1.8 mL of 36 mg of lidocaine with 18 µg epinephrine to 3.6 mL of 36 mg lidocaine with 18 µg epinephrine plus 36 mg of meperidine with 18 µg epinephrine. The addition of
meperidine to the standard lidocaine solution did not increase the anesthetic success of the inferior alveolar nerve block.

Fernandez et al. (17) assessed the anesthetic efficacy of bupivacaine versus lidocaine solutions for the inferior alveolar nerve block. The study concluded that 1.8 mL of 0.5% bupivacaine with 1:200,000 epinephrine was less effective in providing pulpal anesthesia in all teeth, except the first molar, compared with 1.8 mL of 2% lidocaine with 1:100,000 epinephrine. Notably, when pulpal anesthesia was successfully achieved with the bupivacaine solution, it resulted in significantly prolonged duration of lip and pulpal anesthesia when compared to the lidocaine solution, an average of 4 hours versus 2 hours and 24 minutes, respectively. Moore and Dunsky (18) utilized an endodontic model to compare these two solutions (0.5% bupivacaine with 1:100,000 epinephrine and 2% lidocaine with 1:100,000 epinephrine) and found bupivacaine had a significantly longer duration of anesthesia and significantly reduced post-operative pain. Onset and depth of anesthesia were comparable amongst the two solutions with no significant difference noted in these categories.

Rood (19) found that a 5% lidocaine solution with 1:80,000 epinephrine increased pulpal anesthesia when employed as a repeat inferior alveolar nerve block compared to a 2% lidocaine with 1:80,000. Additionally, Rood and Sowray (20) describe over 200 patients undergoing varied dental procedures - from operative to endodontic to surgical - benefiting from the use of a 5% lidocaine solution when 2% lidocaine solution could not provide adequate pain control. Beckett and Gilmour (21) endorse Rood and Sowray’s findings with a case report of a local anesthetic “resistant” patient in whom a 5% lidocaine solution enabled painless dental treatment to be performed.
From the technique standpoint, Montagnese et al.’s (22) use of 1.8 mL of 2% lidocaine with 1:100,000 epinephrine via a Gow-Gates injection was shown to have no difference in anesthetic efficacy when compared to the traditional inferior alveolar nerve block; both techniques resulted in inadequate levels of pulpal anesthesia at 35% and 38%, respectively. Goldberg et al. (23) evaluated anesthetic efficacy among three techniques: the Gow-Gates, the Vazirani-Akinosi, and the conventional inferior alveolar block. No significant differences among the three techniques were noted regarding anesthetic efficacy. These techniques and their potentially enhanced anesthetic efficacy will be further discussed in the Gow-Gates and Vazirani-Akinosi sections of this introduction.

Childers et al. (24) compared the anesthetic efficacy of the inferior alveolar nerve block alone and with the combination of the periodontal ligament injection in mandibular teeth. No statistical difference was noted regarding anesthetic success. However, the combination of the inferior alveolar nerve block and the periodontal ligament injection did result in a higher incidence of pulpal anesthesia for the first 23 minutes of pulp testing in the first molar.

Nist et al. (25) evaluated the incisive nerve block and the combination inferior alveolar and incisive nerve blocks in mandibular anesthesia. The authors used 3.6 mL of 2% lidocaine with 1:100,000 epinephrine for the inferior alveolar nerve block and 1.8 mL of the same lidocaine solution for the incisive nerve block. The combination of the two injections resulted in pulpal anesthesia for the first and second premolars (90% and 85%) for one hour and enhanced pulpal anesthesia in the lateral incisors and first molars. Clark et al. (26) noted that infiltrations effectively supplemented the inferior alveolar nerve block but are not effective when used alone. Kanaa (27) found the supplementation of the
inferior alveolar nerve block (2.0 mL 2% lidocaine with 1:80,000 epinephrine) with a buccal infiltration of 2.0 mL 4% articaine with 1:100,000 epinephrine to significantly improve anesthetic success rates (33% versus 20% for the first molars, 32% versus 24% for the premolars, and 28% versus 7% for the lateral incisors) when compared to the inferior alveolar nerve block alone.

Accessory innervation via the mylohyoid nerve is hypothesized to contribute to inferior alveolar nerve block failure, specifically regarding pulpal anesthesia of the first mandibular molar (28). However, Clark et al. (29) showed that a combination inferior alveolar nerve block and mylohyoid nerve block did not significantly improve pulpal anesthesia, nor does a mylohyoid nerve block predictably ensure pulpal anesthesia in mandibular teeth (29). Likewise, Yonchak et al. (30) found cross-innervation not to be a primary cause of anesthetic failure in human mandibular incisors following an inferior alveolar nerve block.

Needle deflection is also cited as reason for inferior alveolar nerve block failure (31-33) but Steinkrugger et al. evaluated the significance of needle bevel orientation for a successful inferior alveolar nerve block and revealed that needle bevel position away or toward the mandibular ramus does not affect anesthetic success (34). Hannan et al. noted that accurate placement of the needle via ultrasound technology also does not result in more successful pulpal anesthesia, showing that the accuracy of needle placement is not a primary reason for pulpal anesthetic failure in the mandible (35). Berns and Sadove (36) employed radiographic methods to locate the mandibular foramen but discovered it did not increase the rate of anesthetic success. Simon et al. (37) studied accurate placement of solution deposition to the inferior alveolar nerve via a peripheral nerve stimulator and
showed no increase in success rate of pulpal anesthesia when compared with a conventional inferior alveolar nerve block (37).

**Irreversible Pulpitis**

Patients presenting with irreversible pulpitis have additional anesthetic concerns. First, conventional anesthetic methods do not consistently provide adequate pulpal anesthesia (38). Second, nerves originating in inflamed tissue may have higher resting potentials and therefore decreased excitability thresholds that prevent local anesthetic from sufficiently blocking impulse transmission in these areas (39, 40). Third and fourth, an upregulated expression of sodium channels and increased expression of tetrodotoxin-resistant sodium channels in irreversible pulpitis nerve tissue, results in increased resistance to the action of local anesthetics (41, 42). Finally, patients experiencing pain are often apprehensive, which lowers their threshold for pain (38).

**Asymptomatic versus Symptomatic Irreversible Pulpitis**

In comparing clinical studies evaluating anesthetic effects in teeth diagnosed with irreversible pulpitis, the delineation between asymptomatic and symptomatic irreversible pulpitis must be carefully heeded. Anesthetic success rates are not comparable between a diagnosis of asymptomatic irreversible pulpitis – a condition in which the patient is not experiencing active pain or acute symptoms, and symptomatic irreversible pulpitis in which the patient presents with active, quantifiable pain resulting from acute odontogenic
symptoms. A theory that suggests cause for low anesthetic success rates in symptomatic irreversible pulpitis is the inflammation-induced sensitization of peripheral nociceptors by prostaglandins (43). In addition, inflammation produces changes in the central nervous system’s pain processing system (44).

Since success rates of the inferior alveolar nerve block decrease in patients with both asymptomatic and symptomatic irreversible pulpitis, various methods to increase anesthetic success have been studied ranging from supplemental anesthetic techniques and varied anesthetic solutions, to pre-medication and alternative inferior alveolar block techniques. Studies reviewing various pre-medication techniques have found no significant difference in success of the inferior alveolar nerve block in patients with irreversible pulpitis despite the addition of preoperative ibuprofen, ibuprofen/acetaminophen, sublingual triazolam, or vicodin (44-48).

Oleson et al. (45) evaluated the preoperative effect of 800 mg ibuprofen on the success of the inferior alveolar nerve block in patients diagnosed with symptomatic irreversible pulpitis and in moderate-to-severe pain. Forty-five minutes after administration of the ibuprofen or placebo, the 100 patients in the study were given an inferior alveolar block using 3.6 mL 2% lidocaine 1:100,000 epinephrine. Profound lip numbness was verified at 15 minutes and endodontic access initiated. Success was defined as patient sensation of no or mild pain during access and instrumentation as verified by a 170 mm visual analog scale (VAS). No significant difference was noted between the ibuprofen group and the placebo group, success rates were 41% and 35%, respectively.
Simpson et al. (44) studied the preoperative effect of a combination of ibuprofen and acetaminophen on the inferior alveolar nerve block in patients diagnosed with symptomatic irreversible pulpitis. Patients experiencing moderate-to-severe pain were given either a combination of 800 mg of ibuprofen and 1000 mg of acetaminophen or a placebo drug. One hundred patients were included in the study. Once 45 minutes had elapsed, an inferior alveolar nerve block using 3.6 mL of 2% lidocaine with 1:100,000 epinephrine was given. After lip numbness was verified, treatment was started. Success was defined as no or mild pain upon access and instrumentation of the tooth. Results revealed no significant difference between the groups; a success rate of 32% was found among the ibuprofen/acetaminophen group and a success rate of 24% for the placebo group.

Ianiro et al. (46) investigated the effect of preoperative acetaminophen or a combination of acetaminophen and ibuprofen on the success of the inferior alveolar nerve block (IANB) in teeth with symptomatic irreversible pulpitis. The diagnosis was determined by a chief complaint of spontaneous pain as well as an elevated and lingering response to a cold test application. Forty patients were randomly assigned to one of three groups: one group was given 1000 mg of acetaminophen, another group was given 600 mg ibuprofen plus 1000 mg acetaminophen, and the final group was given a placebo drug. Thirty minutes after taking the assigned drug, patients were given an IANB using 3.6 mL 2% lidocaine with 100,000 epinephrine. Fifteen minutes after the IANB injection, a cold test was administered to the tooth. Three outcomes were noted. If the patient felt pain or discomfort upon cold application to the tooth, the inferior alveolar block was considered a failure. If the patient did not report pain upon cold application to the tooth, a rubber dam
was placed and endodontic access initiated. If pain was felt during endodontic access, the inferior alveolar block was considered a failure and supplemental anesthesia was administered. If endodontic access and treatment were accomplished without pain, the inferior alveolar nerve block was documented as a success. Ianiro et al. found an overall success rate of 60% for the three groups combined. The acetaminophen group’s success rate was 71.4%, the combination acetaminophen/ibuprofen group’s success rate was 75.9%, and the placebo success rate was 46.2%. The authors found no significant differences between the groups. One reason for the conclusions reached in this study is that the authors’ sample size in this study was small, resulting in low statistical power.

Aggarwal et al. (49) studied the effect of preoperative ibuprofen and ketorolac on the inferior alveolar nerve block in patients with symptomatic irreversible pulpitis. Sixty-nine adults experiencing “active pain” in a mandibular molar were included in the study and assigned to one of three groups. The authors did not disclose the patients’ VAS scores that described their initial pain. The first group received 600 mg ibuprofen, the second received 20 mg ketorolac, and the third group received a placebo drug. An hour after administration, each patient received an inferior alveolar nerve block using 1.8 mL 2% lidocaine with 1:200,000 epinephrine. Endodontic therapy was initiated once lip numbness was verified 15 minutes after administration of the inferior alveolar nerve block. Success was defined as experiencing none or mild pain on a Heft-Parker visual analog scale during endodontic treatment. None of the groups achieved a 100% success rate; the placebo group had a 29% success rate, the ibuprofen premedication group had a 27% success rate and the ketorolac premedication group had a 39% success rate. The authors claim that all of the patients experienced a significant decrease in their active pain.
after administration of the inferior alveolar nerve block but do not disclose initial or post-injection VAS scores. No significant difference was found among the three groups in regard to anesthetic success as defined by the authors (49).

Modaresi et al. (50) assessed ibuprofen, acetaminophen-codeine, and placebo premedication on the depth of anesthesia achieved during treatment of teeth with symptomatic irreversible pulpitis. Patients included in the study were experiencing “active pain” in one mandibular molar and asked to quantify their pain on a Heft-Parker visual analog scale (VAS). Inclusion criteria also consisted of prolonged responses to cold and EPT testing on the mandibular molar. Sixty patients participated and were randomly assigned to one of three groups: premedication with 300 mg ibuprofen, 300 mg acetaminophen and 20 mg codeine premedication, or a placebo drug. An hour after oral administration of the randomly assigned premedication, an inferior alveolar block was administered using 1.8 mL 2% lidocaine with 1:80,000 epinephrine. A ten-minute waiting period was observed before evaluation of the patient was done to determine lower lip and tongue tip numbness. If numbness in these areas was not achieved, a second inferior alveolar nerve block was administered using 1.8 mL 2% lidocaine with 1:80,000 epinephrine. Once lip numbness was noted, an electric pulp tester (EPT) measurement was recorded as well as a “tooth sensitivity level” or TSL. The authors describe the index as ranging from 1 to 0 where a TSL of 1 indicates a tooth responsive to EPT at low stimulation and a TSL of 0 when the tooth is not responsive to EPT. Significantly lower TSLs were observed after intervention with acetaminophen/codeine and ibuprofen with a significant difference noted between the acetaminophen/codeine and ibuprofen groups. The authors concluded that ibuprofen (if not contraindicated) is superior for achieving
“deep anesthesia” compared to acetaminophen/codeine and placebo when given one hour before local anesthesia in patients with symptomatic irreversible pulpitis. TSL levels were not confirmed with endodontic access or treatment and therefore are not of clinical consequence.

Parirokh et al. (51) studied the success of the inferior alveolar nerve block in mandibular first or second molars diagnosed with asymptomatic irreversible pulpitis after oral administration of either ibuprofen or indomethacin. The randomized, double-blind study included 150 patients separated into three groups: 600 mg ibuprofen, 75 mg indomethacin, or placebo drug. Qualification criteria for the mandibular molars included a normal radiographic appearance and an exaggerated (10 seconds long) and moderate-to-severe pain response to cold testing as verified by a Heft-Parker VAS. Spontaneous, acute, or existing pain was not incorporated into the inclusion criteria. Though the authors classify their subjects as diagnosed with irreversible pulpitis, their subjects were not experiencing symptoms associated with the target tooth therefore a more descriptive diagnosis of asymptomatic irreversible pulpitis was appropriate. The authors found success rates for the placebo, ibuprofen, and indomethacin groups were 32%, 78%, and 62%, respectively. The authors concluded that administration of preoperative ibuprofen and indomethacin significantly increased the success rate of the inferior alveolar block in patients with molars they diagnosed as irreversible pulpitis, presenting asymptptomatically (51).

Prasanna et al. (52) reviewed the efficacy of lornoxicam and diclofenac potassium in patients diagnosed with irreversible pulpitis. One hundred and fourteen patients with irreversible pulpitis of a mandibular posterior tooth were divided into three groups of 38
and were randomly assigned to a placebo, lornoxicam (8 mg), or diclofenac potassium (50 mg) group. Subjects received their respective premedication one hour before the initiation of treatment. After one hour an inferior alveolar nerve block was administered and subjective lip numbness was confirmed at 15 minutes. A cold test was administered to the target tooth. If patients felt cold then they were considered failures and received supplemental anesthesia to accomplish endodontic therapy. If patients did not respond to the cold test, endodontic access was initiated with success of the inferior alveolar nerve block defined as the absence of pain during access and root canal instrumentation. The authors’ inclusion criteria did not discriminate between patients experiencing asymptomatic and symptomatic irreversible pulpitis. Though patients rated their initial pain on a Heft-Parker VAS, a certain value was not required. Patients responding negatively to the cold test also did not necessarily experience a successful inferior alveolar nerve block. Percentages of teeth giving a negative response to the cold test are as follows: 42.8 % (placebo), 67.8% (diclofenac potassium), and 78.5% (lornoxicam). Success rates of the inferior alveolar nerve block were found to be: 28.5% (placebo), 53.5% (diclofenac potassium), and 71.4% (lornoxicam). The authors concluded that among this group of emergency patients, experiencing some amount of pain as reported on a VAS, pre-operative administration of 8 mg lornoxicam significantly improved the efficacy of the inferior alveolar nerve block as compared to the placebo group.

Li et al. (53) conducted a meta-analysis and systematic review assessing randomized controlled clinical trials evaluating the effect of preoperative oral non-steroidal anti-inflammatory drugs (NSAIDs) on the success of the inferior alveolar nerve block. Electronic and hand-searching various scientific journal banks yielded 137
potential citations of which seven articles (44-46, 49-52) met the authors’ inclusion for criteria in the analysis. Meta-analysis was performed and the authors concluded that there is evidence that pre-emptive oral NSAIDs might have a good effect on the inferior alveolar nerve block and are safe in increasing the injection’s success. The studies included were just described previously.

Lindemann et al. (47) studied the effect of sublingual triazolam on the success of the inferior alveolar nerve block in patients with symptomatic irreversible pulpitis. The authors hoped to find that patients’ anxiety and therefore reaction to endodontic treatment would be reduced, thereby increasing the success rate of the inferior alveolar nerve block. Fifty-eight patients were included in the study and randomly received either a 0.25 mg sublingual tablet of triazolam or placebo drug 30 minutes before administration of a conventional inferior alveolar nerve block. Anesthetic success rates were found to be 43% for the triazolam group and 57% for the placebo group with no significant difference noted between the two groups. Pretreatment anxiety ratings in the two groups, as determined by a Corah dental anxiety questionnaire, were also found to have no significant difference, suggesting that conscious sedation via administration of 0.25 mg of sublingual triazolam is not a clinically useful method to increase inferior alveolar nerve block success in that patient population.

In an effort to identify the most successful way in which to anesthetize and therefore treat patients with symptomatic irreversible pulpitis in mandibular posterior teeth, several studies have examined various anesthetic solutions and techniques in patients with this diagnosis. In separate studies, Tortamano et al. (54) and Claffey et al. (55) compared the anesthetic efficacy of 2% lidocaine with 1:100,000 epinephrine versus
4% articaine 1:100,000 epinephrine for an inferior alveolar nerve block in patients experiencing symptomatic irreversible pulpitis in mandibular posterior teeth. Both studies revealed no significant difference between the two solutions, noting neither anesthetic solution effectively managed pain during treatment (54, 55).

Sampaio et al. compared the anesthetic efficacy of 3.6 mL of 2% lidocaine with 1:100,000 epinephrine and 3.6 mL of 0.5% bupivacaine with 1:200,000 epinephrine in seventy patients with symptomatic irreversible pulpitis in a mandibular molar. The study revealed no statistically significant difference between the solutions regarding pain felt during the pulpectomy procedure; all patients (100%) reported subjective lip anesthesia 10 minutes after the inferior alveolar nerve block yet 20% of patients in the bupivacaine group and 37.1% of patients in the lidocaine group did not experience successful anesthesia (as defined by no or mild pain throughout treatment) during the procedure. Neither of the solutions resulted in effective pain control during treatment of mandibular molars with irreversible pulpitis (56).

Matthews et al. evaluated the effect of 1.8 mL infiltration of 4% articaine with 1:100,000 epinephrine in patients with symptomatic irreversible pulpitis when the inferior alveolar nerve block failed (57). Fifty-five patients were included in the study and received an inferior alveolar nerve block. Subjective lip numbness was verified at 15 minutes post-injection at which time endodontic access was initiated. If patients experienced moderate-to-severe pain as noted on a Heft-Parker VAS, treatment was stopped and an infiltration of 4% articaine with 1:100,000 epinephrine was administered. A modest success rate of 58% was achieved for supplemental anesthesia in these patients, but the study concluded that a supplemental infiltration of 4% articaine with 1:100,000
epinephrine did not provide predictable pulpal anesthesia for all patients requiring profound anesthesia during endodontic treatment of symptomatic irreversible pulpitis (57).

This is not the case in asymptomatic teeth where Kanaa et al. evaluated whether or not a buccal infiltration of 4% articaine with 1:100,000 epinephrine would enhance a 2.0 mL 2% lidocaine with 1:100,000 epinephrine inferior alveolar block. EPT values of the mandibular dentition confirmed that an inferior alveolar nerve block supplemented with a buccal infiltration of 4% articaine with 1:100,000 epinephrine was significantly more successful (91.7% in molars, 88.9% in premolars, 77.8% in laterals) than an inferior alveolar block alone (55.6% in molars, 66.7% in premolars, and 19.4% in laterals) (58).

Aggarwal et al. further studied the supplemental buccal and lingual infiltrations of 4% articaine with 1:200,000 epinephrine versus 2% lidocaine with 1:200,000 epinephrine after an inferior alveolar nerve block in patients with irreversible pulpitis and revealed increased success rates with a statistical difference in articaine success versus lidocaine success (59). However, neither supplemental technique provided acceptable success rates; the supplemental articaine infiltration produced a 67% success rate and the supplemental lidocaine infiltration produced a 47% success rate (59).

Nusstein et al. noted that in treating posterior teeth diagnosed with symptomatic irreversible pulpitis, the supplemental intraosseous injection of 2% lidocaine with 1:100,000 epinephrine was successful when conventional techniques (maxillary infiltration and mandibular nerve blocks) failed. Among 26 mandibular posterior teeth, 21 (81%) required an intraosseous injection. Nineteen teeth (90%) were reported as achieving anesthetic success, defined by the authors as pain-free endodontic access and instrumentation (60).
Bigby et al. included 37 subjects in his study and examined the success of articaine as an intraosseous injection solution and found that it too provided success (86% of the time) in achieving pulpal anesthesia in mandibular posterior teeth diagnosed with symptomatic irreversible pulpitis in which the inferior alveolar nerve block failed to provide adequate pulpal anesthesia (61).

Reisman et al. evaluated the anesthetic efficacy of 3% mepivicaine as an intraosseous injection in symptomatic irreversible pulpitis. Forty-eight patients actively experiencing pain from a vital, posterior mandibular tooth were included in the study. Each patient was anesthetized with 1.8 mL 2% lidocaine with 1:100,000 epinephrine via an inferior alveolar nerve block and tested every minute for five minutes. If profound lip numbness was not achieved within 5 minutes, an additional inferior alveolar nerve block was administered and retested for 5 minutes. All patients had profound lip numbness after the initial or additional inferior alveolar nerve block. If the patient responded positively to the EPT at 5 minutes after the clinically successful inferior alveolar nerve block, an intraosseous injection of 1.8 mL of 3% mepivicaine was administered. The intraosseous injection was also administered to patients who did not respond to the EPT test but felt pain upon endodontic access, pulpal exposure, or canal instrumentation. A second intraosseous injection was administered in the same site if the patient again felt pain during treatment. The authors found the inferior alveolar nerve block to be 25% successful with the first intraosseous injection increasing the success rate to 80% and the second intraosseous injection increasing the success rate to 98%. Reisman et al. concluded that for mandibular posterior teeth, 3% mepivicaine administered as an intraosseous injection significantly improves anesthetic success in patients with
symptomatic irreversible pulpitis (62). The potential benefit of utilizing mepivicaine is that it has been found to not transiently elevate the heart rate when given as an intraosseous injection (63). Replogle et al. compared the cardiovascular effects of an intraosseous injection using 1.8 mL of 2% lidocaine with 1:100,000 epinephrine versus 1.8 mL 3% mepivicaine and found that 67% of patients experienced a transient increase in heart rate that might be attributable to the effect of epinephrine. In 79% of those patients, the heart rate returned to within 5 beats of baseline values within four minutes of solution deposition. No significant difference was found in the heart rates of those subjects receiving 3% mepivicaine injections (63).

Kanaa et al. noted that since the inferior alveolar block does not always allow for pain-free treatment of mandibular teeth with irreversible pulpitis, supplementary buccal infiltration with 4% articaine with epinephrine and an intraosseous injection with 2% lidocaine with epinephrine are more likely to allow pain-free treatment than intraligamentary and repeat inferior alveolar nerve block injections with 2% lidocaine with epinephrine (64). This randomized clinical trial included 182 patients diagnosed with irreversible pulpitis as determined by clinicians not associated with the trial. The authors do not mention if the patients presented with active pain or how the diagnosis of the irreversible pulpitis was obtained. All patients received 2.0 mL 2% lidocaine with 1:80,000 epinephrine as an inferior alveolar nerve block. Pulp testing with an EPT was completed on the tooth every two minutes for 10 minutes or until it was possible to achieve a maximum reading of 80 without sensation, whichever occurred sooner. Patients who achieved pulpal anesthesia within 10 minutes received their treatment of choice, pulpal extirpation or tooth extraction. Patients requesting tooth extraction received
additional injections with 2% lidocaine with epinephrine in order to establish soft tissue anesthesia. Those that did not achieve an 80 reading without sensation 10 minutes after the inferior alveolar block, or felt pain during their treatment received one of four supplementary injections as determined by a web-based program for randomization. One hundred subjects were divided into four groups of 25, indicating the study may be underpowered. The first method was a repeated lidocaine inferior alveolar nerve block using 2.0 mL of 2% lidocaine with 1:80,000 epinephrine. The second method was a buccal infiltration of 2.0 mL 4% articaine with 1:100,000 epinephrine. The third method was an intraligamentary injection of 0.18 mL of 2% lidocaine with 1:80,000 epinephrine deposited into the periodontal ligament on the mesiobuccal aspect of each root. The fourth method was an intraosseous injection using 1.0 mL of 2% lidocaine with 1:80,000 epinephrine. Pulp sensitivity of the tooth was tested with an EPT 2 minutes after the supplemental injection and again at 5 minutes if an 80 reading was not achieved at 2 minutes. Patients were excluded from the study if it was not possible to achieve an 80 EPT reading without sensation 5 minutes after the supplemental injection. The authors noted that more successful treatments were associated with 4% articaine with 1:100,000 infiltration (84%) or intraosseous injection of 2% lidocaine with 1:80,000 (68%) than with intraligamentary injections (48%) or a repeated inferior alveolar nerve block (32%) (64).

The requirements for diagnosis of irreversible pulpitis, arguably one of the most important inclusion criteria in the study, were not explained or quantified by the authors. Therefore, it is difficult to identify whether the results of this study communicate best possible clinical outcomes for patients with irreversible pulpitis in which the inferior alveolar nerve block fails. It is possible that both asymptomatic and symptomatic cases of irreversible
pulpitis could have been included in the study and as seen in our review, these two groups of patients have different anesthetic thresholds, requirements, and success rates.

The significance of needle deflection in success of the inferior alveolar nerve block in patients with symptomatic irreversible pulpitis was studied by Kennedy et al. (65). Sixty-four adult patients were included and randomly received 2.8 mL of 2% lidocaine with 1:100,000 epinephrine with either a conventional IANB or a bidirectional-rotation-technique, using the Wand II computer-assisted anesthesia system. Due to the residual amount of anesthetic solution in the Wand II system after deposition, the injection volume per cartridge was 1.4 mL. Therefore each technique utilized 2.8 mL anesthetic solution per subject. A total of five patients were eliminated from the study due to lack of profound lip numbness at 10 minutes. Those that continued in the study received emergency endodontic treatment (access and instrumentation of the tooth). Success of the inferior alveolar nerve blocks was defined as the ability to access and instrument the tooth without pain (VAS score of zero) or with mild pain (VAS score ≤54 mm). The study revealed no significant differences between the success rates of these two techniques, indicating that the orientation of the needle bevel and subsequent potential for deflection, does not affect pulpal anesthesia (65).

To address the symptomatic irreversible pulpitis patient’s anxiety as a potential negative effect on anesthetic success, Stanley et al. showed that the administration of nitrous oxide (30-50%) showed statistically significant improved rates of inferior alveolar nerve success in patients with symptomatic irreversible pulpitis. This study indicated that the effect of nitrous oxide mitigates patients’ apprehension regarding their pain and the projected pain of the pulpectomy procedure (66). Patients receiving nitrous oxide during
endodontic treatment of a symptomatic irreversible tooth had a 50% success rate of the inferior alveolar block whereas patients receiving the placebo (room air/oxygen) had a 28% success rate for the same injection (66). The analgesic effect of nitrous oxide may be responsible for the increased success rate noted in this study.

McCartney et al. studied the injection pain of the inferior alveolar nerve block in patients with irreversible pulpitis. This retrospective study evaluated one hundred and two patients presenting with symptomatic irreversible pulpitis who were asked to rate the pain of insertion, placement and deposition during these phases of the inferior alveolar nerve block. The authors concluded that 57% to 89% of patients presenting with this diagnosis have the potential for moderate to severe pain with the inferior alveolar nerve block (67). This differs from rates of pain for these same inferior alveolar block injection phases in asymptomatic patients where Nusstein et al. (68) reported an incidence of moderate-to-severe pain ranging from 14% to 22% during insertion and, in a different study also by Nusstein et al., 22% to 56% during needle placement (69).

Most recently, Dou et al. reviewed the effect of a supplemental lingual infiltration on mandibular molars diagnosed with irreversible pulpitis once an inferior alveolar block plus buccal infiltration were administered (70). Eighty patients experiencing moderate-to-severe pain in response to cold stimulation with an ice stick and normal periapical radiographic appearance of a first or second mandibular molar were included in the study. This diagnosis was made by an independent endodontist. As mentioned previously, the absence of spontaneous pain in this group of patients makes a diagnosis of asymptomatic irreversible pulpitis more appropriate. A conventional inferior alveolar block was administered using 4 mL of 2% lidocaine with 1:100,000 epinephrine. The authors
divided the subjects into two groups: the buccal infiltration (BI) group and the buccal plus lingual infiltration (BLI) group. In the BI group, 0.9 mL of 4% articaine with 1:100,000 epinephrine was administered 10 minutes after the IANB once confirmation of lip numbness was verified. A mock lingual infiltration of saline was administered to these patients. In the BLI group, the subjects received the same buccal infiltration as the BI group and the same dose and anesthetic for a lingual infiltration (0.9 mL of 4% articaine with 1:100,000 epinephrine). If patients complained of moderate-to-severe pain during endodontic access, the initial instrumentation was omitted at the first visit. The authors found that buccal plus lingual infiltration did not improve anesthetic success – defined by the authors as less than moderate discomfort during endodontic access - compared to buccal infiltration alone. No significant differences were found among total success rates – defined by the authors as less than moderate pain during initial root canal instrumentation - in the BI (70%) and BLI (62.5%) groups.

Alternative techniques for the Inferior Alveolar Nerve Block

The Gow-Gates Technique

Gow-Gates introduced a new technique for mandibular anesthesia in 1973 (71). The injection uses extraoral landmarks and the target site is the neck of the mandibular condyle. The needle comes to rest at a depth of 25 mm, at which point the anterior surface of the mandibular condyle is sounded. Anterior to this area is the common nerve trunk of inferior alveolar, lingual, and buccal nerves. When the mouth is open, as described in the Gow-Gates technique, the condyle is in a more forward position, allowing the deposition
of solution to approximate the common nerve trunk by less than 1 cm (71). The deposition of the anesthetic solution on the one, higher position on the neck of the condyle anesthetizes the inferior alveolar, lingual, buccal and supplementary nerves simultaneously (71). Higher insertion placement than the standard inferior alveolar block allows for successful mandibular conduction anesthesia rather than deposition at a level below the mandibular foramen, a possible reason for failed mandibular anesthesia (72).

**The Gow-Gates Technique In Asymptomatic Vital Teeth**

A number of studies (73-75, 77, 78) have shown higher success rates with the Gow-Gates technique (92 to 100%) than the conventional inferior alveolar nerve technique (65 to 86%). Levy found 3.0 mL anesthesia superior to 1.8 mL using the Gow-Gates technique, and that the Gow-Gates block provided superior mandibular anesthesia during third molar surgical removal than the conventional block (74). The authors used a “split mouth technique,” in which the 26 subjects in the study presented for nonemergency, bilateral mandibular third molar extraction, receiving a Gow-Gates technique injection on one side and a standard inferior alveolar nerve block on the other. Each subject was given a random number, odd numbered patients received the Gow-Gates block first and the first injection was alternated between left and right sides. Surgery was not initiated until 10 minutes post-injection, and always begun on the side of the conventional block due to the author’s theory that “greater vascularity was expected at the mandibular foramen” and no epinephrine was used (the authors used prilocaine hydrochloride 4% without vasoconstrictor). Levy found no significant difference in the
perception of pain associated with either injection, however he did find that completely satisfactory anesthesia (classified as the patient feeling no discomfort whatsoever and not requiring anesthetic reinforcement) was significantly higher in the Gow-Gates (96% of the operative sites) versus the conventional block (65%). This may be due to the additional time granted for the Gow-Gates operative sites since surgery was always commenced on the conventionally blocked side.

Malamed’s evaluation of the Gow-Gates mandibular block in 4,275 cases claimed greater success rate, decreased positive aspiration rate, and fewer postinjection problems than the conventional inferior alveolar nerve block technique (75). The 4,275 injections are claimed to have benefited directly from Malamed’s personal involvement over a period of 5 years in the clinics at the University of Southern California. Of the 4,275 injections, 48.4% were utilized as the primary technique for mandibular anesthesia and the remaining 51.8% in an attempt to obtain “clinically adequate pain control when the conventional technique had proved inadequate” (75). Adequate pain control was defined using a system devised by Dobbs and DeVier (76), and categorized as “that which did not require reinjection to alleviate any discomfort,” or Grades A and B combined. Grade A was defined as completely satisfactory anesthesia and Grade B as subject felt slight pain but does not require reinforcement. Grade C was defined as feeble anesthesia requiring another injection. The study does not indicate which procedures were performed on the subjects, or the level of experience the operators had with this injection. Malamed notes that a period of 1 to 2 weeks utilizing the injection for all patients requiring mandibular anesthesia is necessary in order to gain clinical experience with this injection, (75).
Another bilateral third molar removal study revealed a higher success rate of the Gow-Gates technique over conventional methods but acknowledges the limitations of the Gow-Gates technique as slower onset of anesthesia, variable buccal nerve anesthesia, and increased intraoperative bleeding (77). The overall success rate, as determined by altered lip sensation 10 minutes post-injection, was significantly higher for the Gow-Gates at 95%, than for the conventional inferior alveolar block at 79%. The injection techniques per side were decided at random; the injection and surgery was performed on the first side before the second side’s treatment was initiated. A volume of 1.8 mL 2% lidocaine with 1:100,000 epinephrine was utilized for the Gow-Gates technique, performed according to Malamed’s description of the injection (75), and 1.6 mL of the same anesthetic was used for the inferior alveolar nerve block, 0.2 mL for the lingual nerve block and 0.5 mL for the buccal nerve block. All patients received an intravenous premedication with diazepam, titrated to a clinically determined endpoint or maximum dosage of 0.3mg/kg of body weight. Though the conventional block had higher numbers of subjects noting altered lip sensation at 5 minutes (72.5% versus 45% for the Gow-Gates technique), there was a significant difference in 10 minutes post-injection with 95% of the Gow-Gates subjects reporting lip onset and 79% of the conventional injection. The mean time of onset for the Gow-Gates was determined to be 7.68 minutes and 5.08 minutes for the conventional block. The quality of anesthesia was noted using an anesthesia score of 1 indicating no pain during the procedure, and scores greater than 1 indicating that some pain was experienced. Patients receiving the Gow-Gates injection noted that pain occurred during reflection of the buccal mucoperiosteal flap and/or sectioning of the impacted teeth. The surgeon rated the degree of intraoperative bleeding as follows: 1= minimal, 2= normal, 3=
excessive. Nine patients, or 23% of the Gow-Gates group were classified as excessive bleeders whereas no patient was noted to have excessive intraoperative bleeding (77). For conventional endodontic purposes, in which buccal flaps are not laid nor teeth sectioned, the significant difference between the Gow-Gates injection and the conventional inferior alveolar block found by Sisk is clinically valuable in that the Gow-Gates injection technique may be better suited to achieve a successful inferior alveolar block.

Cruz et al. also found a higher rate of anesthesia when using the Gow-Gates technique (78). In their extraction model, the authors evaluated 45 patients divided into three groups of 15: a conventional inferior alveolar block group, a Gow-Gates group, and a Vazirani-Akinosi group. The subjects in each group received 1.8 mL of anesthetic solution, which the authors do not identify. Patients were asked the following questions during the injection: “Does it hurt?” and “Are you comfortable with this method?” At ten minutes post-injection, an explorer puncture test was administered to evaluate soft tissue anesthesia in areas supplied by the mandibular nerve, e.g. posterior buccal and lingual mucosa, lower lip, and tip of the tongue. Once this was accomplished, the extraction procedure was initiated. Patients were asked to rank their discomfort during the procedure using three grades. Grade A signified completely satisfactory anesthesia, Grade B signified the sensation of some discomfort or pain but not requiring additional anesthesia, and Grade C signified inadequate anesthesia requiring another block. Professed comfort with the injection technique was recorded as follows: 9 subjects (60%) in the conventional technique group, 13 subjects (86.7%) for the Vazirani-Akinosi group, and 12 subjects (80%) for the Gow-Gates group. Results for the grading of anesthesia showed that among the subjects per group, 10 subjects (66.7%) in the conventional technique group, 9 subjects
(60%) in the Vaziri-Akinosi group, and 12 subjects (80%) in the Gow-Gates group reported a Grade A. Cruz et al. conclude that the Gow-Gates appeared to be the most effective technique for local anesthesia during 3rd molar extraction while the Vazirani-Akinosi technique appeared to be most acceptable for patients (78). However, due to the small sample sizes in this study, the results may be questionable.

In contrast to the higher success rates described above, Todorovic et al. (79) found a higher success rate with the conventional inferior alveolar nerve block (96.6%) than the Gow-Gates block (90.0%). Todorovic also noted that the Gow-Gates technique showed the longest anesthesia onset time at 1-20 minutes with a median time of 7 minutes (the conventional block range was 1-7 minutes, median 4 minutes). In this study, the depth of anesthesia was determined according to discomfort experienced during tooth extraction (the authors do not note which mandibular teeth were extracted among the 90 subjects) as well as pin pricks of mandibular oral mucosa. It must be noted that mucosal stick evaluation of the mandibular mucosa has been proven to be an inconsistent indicator of pulpal anesthesia, however the lack of soft tissue anesthesia was found to indicate that the inferior alveolar nerve is not blocked successfully (4). Successful depth of anesthesia during extraction was defined as experiencing no pain, pressure, or moderate pain. Frequency of successful anesthesia was noted as 96.6% for the conventional method and 90.0% for the Gow-Gates method. If moderate pain is not included in the definition (as it is not in our study methods) then the frequency of anesthesia for the conventional method drops from 96.6% to 90.0% and the Gow-Gates rate from 90.0% to 76.6% (79).

Agren and Danielsson studied 12 subjects with healthy asymptomatic teeth and found no significant difference among the conventional block and the Gow-Gates
technique regarding analgesic effect in the pulps and vestibular and lingual mucosa at different time intervals (80). The study noted a longer time period for onset and complete analgesia with the Gow-Gates injection – as long as 45 minutes in one case (80). The study is underpowered with the inclusion of only 12 subjects.

Montagnese et al. performed a comparative study and found that among forty subjects, each of which received both injections, no significant differences were found among the injections regarding soft tissue numbness or pulpal anesthesia (22). The senior author administered the Gow-Gates injection to twenty patients and the conventional IANB injection to the other twenty patients. Ten days later, each group received the injection technique that was not given at the initial appointment. The subjects ranged in age from 14-68 years of age and inclusion criteria consisted of good health, no medication use, and no allergic or toxic reaction to a local anesthetic. Testing of the teeth included a sharp dental explorer pressed into the attached gingiva at the buccal and lingual aspect of the canine and the buccal aspect of the first mandibular molar. These locations were chosen in order to assess the inferior alveolar, lingual, and long buccal nerves. As described above, it has since been noted that stimulation of the attached gingiva does not adequately or consistently indicate pulpal anesthesia or numbness of the inferior alveolar nerve. EPT testing was also performed on the mandibular permanent lateral incisor, which was free of caries, restorations, and showed no signs of pathology. Both injections yielded a 98% perceived overall numbness and lip numbness. EPT testing at 10 minutes post-injection revealed 38% with a negative response with the conventional technique and 35% with a negative response using the Gow-Gates technique (22). The authors noted two factors related to the lack of profound anesthesia associated with the lateral incisor.
First, a slower onset of anesthesia with the Gow-Gates injection has been reported by Malamed: 5-7 minutes versus 3-5 minutes for the conventional technique (75). Malamed noted that slower onset is primarily due to the size of the nerve trunk being anesthetized and the distance of the nerve trunk from the deposition site (5-10mm) (6). The second factor Montagnese et al. addressed in the lack of profound anesthesia noted in their study is the central core theory of the nerve bundle, which results in the distal nerves – those that supply the central incisors - being the last anesthetized. The authors noted that a 10 minute post-injection interval time is likely insufficient in establishing complete anesthesia of the lateral incisor. Furthermore, Montagnese et al. conclude that “longer time interval is needed, regardless of the technique, for the onset of profound mandibular anesthesia.” (22)

Hung et al. also found the two techniques (conventional and Gow-Gates) were equivalent (81). Using 162 subjects requiring 3rd molar extractions, Hung’s group analyzed pulpal anesthesia with an EPT at 0, 5, 10, 15, and 60 minutes. Extraction of the 3rd molar occurred only once anesthetic success was achieved, defined as the EPT reading reaching the maximum output of 80 (81). All subjects (100%) achieved lip numbness with molar EPT readings at 15 minutes of 88% for the conventional inferior alveolar nerve block technique, and 83.9% for the Gow-Gates technique (81). No significant difference (p>0.05) between the two methods was found by Hung’s group.

Goldberg et al. (23), in asymptomatic vital teeth, found the ranges of successful anesthesia were 25% to 62% (inferior alveolar technique) and 16% to 44% (Gow-Gates technique). There was no significant difference (p>0.05) in success among the two
techniques. However, the Gow-Gates technique resulted in a statistically slower onset of pulpal anesthesia than the inferior alveolar nerve block.

**The Vazirani-Akinosi Technique**

Akinosi introduced his technique for mandibular anesthesia in 1977 (82). However, Vazirani also described a similar technique in 1960 (83) so the name was changed to the Vazirani-Akinosi technique (6). The injection is a closed mouth technique with the landmarks for needle insertion being the mucogingival junction of the maxillary second molar. This technique is indicated when there is limited mandibular opening (for example trismus or ankylosis), which precludes the use of the inferior alveolar or Gow-Gates techniques. Vazirani notes additional indications such as: when the conventional nerve block has failed; the presence of an acute or chronic infection in the submandibular space; patients with facial fractures in the maxilla and/or mandible; nervous or apprehensive patients; and pediatric patients (83).

**The Vazirani-Akinosi Technique In Asymptomatic Vital Teeth**

Gustainis and Peterson note that an intraoral closed-mouth technique, as described by Vazirani and Akinosi, provides a welcome alternative for a mandibular nerve block due to ease of administration, few postoperative side effects, and most importantly – its application in patients with limited mouth opening resulting from trismus, fear, or sedation (84). Gustainis and Peterson duly note that anesthetic failure of this injection is “almost
always caused by failure to appreciate the flaring nature of the ramus,” and suggest that the correct advancement of the needle is medial to the coronoid process such that the inserted tip lies just medially to the neck of the condyle (84). Inadequate anesthesia is caused by placement too far medially, caused by failure to direct the needle tip laterally as it is advanced (84).

Sisk et al. utilized the 3rd molar extraction model to assess the efficacy of the Akinosi technique versus the conventional technique (85). Twenty patients were chosen requiring equally difficult extractions (as determined clinically and radiographically) that would require the reflection of mucoperiosteal flaps and removal of surrounding bone. The subjects received either injection at random; both injection and surgery were accomplished on one side before injecting and initiating surgery on the other side of the mouth. Five minutes after administration of the first injection (1.8 mL 2% lidocaine for the Akinosi injection, and 1.6 mL for the inferior alveolar nerve block, 0.2 mL for the lingual nerve block, and 0.5 mL for the buccal nerve block), the patient was questioned regarding altered lip sensation. If the response was negative, another 5 minutes were allowed to elapse. If, at 10 minutes, the patient was not experiencing lip paresthesia, the injection was repeated. Sisk found that the 5-minute onset was effective 90% of the time for the Akinosi group and 85% of the time for the conventional technique. At 10 minutes the injections were identical with both groups at 90% (85). Two patients (10%) required second Akinosi injections and two patients (10%) required a second inferior alveolar nerve block (85). In these patients, onset after reinjection was noted within 5 minutes (85). No supplemental intraoperative injections were required. Sisk et al. found no significant difference in the quality of anesthesia between the two techniques. The group
reported that though pain was noted during surgery in three patients receiving the conventional technique and four receiving the Akinosi technique, the pain was “transient” and did not require reinjection. Pain values were not quantified by the subjects. Numbers utilized in this study are low and given the indication that the Akinosi, like the Gow-Gates injection, has a longer onset time (23), it may be that 5 and 10 minute intervals are not sufficient to note a successful inferior alveolar block.

Todorovic et al. found the Vazirani-Akinosi technique was quite similar to the conventional inferior alveolar nerve block regarding time of onset with the conventional method at a median onset of 4 minutes (range of 1-7) and the Akinosi at a median onset of 3 minutes (range of 1-11) (79). Based on discomfort felt during tooth extraction (the authors do not indicate which mandibular teeth were extracted among the 90 subjects) the depth of anesthesia was assessed. Fifteen of thirty (50%) of the subjects receiving the Akinosi injection experienced either pressure or no pain, while the remaining 15 patients experienced moderate or severe pain. The frequency of anesthesia achieved is described as 76.6% for the Akinosi injection, as compared to 90% for the conventional injection because moderate pain was included in the author’s definition as successful anesthesia (79). Even with this inclusion, these results reveal a significant difference between the Akinosi and conventional inferior alveolar technique. As in the Gow-Gates analysis, if the moderate pain group is not included in the definition of successful anesthesia (as per our study’s methods) the Akinosi’s successful anesthesia rate (defined as patients experiencing no pain or simply pressure) drops from 76.6% to 50.0%.

Donkor et al. (86) Yücel et al. (87) and Gonzales et al. (88) found the conventional inferior alveolar nerve block was superior to the Vazirani-Akinosi technique. Donkor et
al.’s mandibular posterior tooth extraction model evaluated 200 patients who were randomly assigned to receive either the conventional or the “closed-mouth” (Akinosi) technique using 1.5-2.0 mL of 2% lignocaine with 1:100,000 adrenaline per injection. Donkor’s group, like Sisk’s study, evaluated patients at 5 minute and 10 minute post-injection times, reinjecting patients for the second time (with the same injection technique) at 10 minutes if lip paresthesia was not achieved. Successful anesthesia was defined as no pain upon probing in areas supplied by the inferior alveolar nerve, lingual nerve or long buccal nerve. If anesthesia was still unsuccessful after the second injection, the alternate technique was employed on the third occasion. Donkor et al. found the conventional technique to be significantly more successful in achieving inferior alveolar nerve anesthesia with 97% success versus a 79% success rate for the Akinosi technique (86).

Lip numbness at 5 minutes was reported to be 87% for the conventional technique and 55% for the Akinosi technique (86). The need for supplementary injections (required for either the inferior alveolar nerve or lingual nerve) was significantly greater in the Akinosi group (29%) versus the conventional group (8%) (86).

Yücel et al. also utilized a tooth extraction model and studied 250 patients requiring extraction of lower first or second molar teeth (87). In all cases injections of 2.0 mL lignocaine hydrochloride with 1:200,000 epinephrine were given, until contact with the mandibular ramus or a depth of 25-30 mm was reached for the conventional and Akinosi injections, respectively. Altered lip sensation was noted at or under 5 minutes, or at 10 minutes if no change in lip sensation was noted, a supplementary injection was given. Adequacy of tissue anesthesia was determined by probing the lower lip, and on the labial and lingual gingival of the first molar. Successful anesthesia was defined as no pain
upon probing. The conventional technique group was found to have a 98% success rate while the Akinosi group had a 76% success rate (87). A supplementary injection was required in 6% of the conventional technique subjects and 29% of the Akinosi subjects. Within 5 minutes, 88% of the conventional injection subjects experienced complete numbness of the lower lip, whereas only 51.2% of Akinosi patients reported the same (87).

Gonzalez et al. evaluated 56 subjects in a lower molar extraction model to compare the conventional or “direct” mandibular nerve block and the Akinosi technique (88). Twenty-eight subjects received the conventional technique; no anesthetic failures were recorded within this group and the first indications of lower lip numbness (onset) were recorded at an average of 2.9 minutes. Of the 28 subjects receiving the Akinosi injection, two subjects were recorded as anesthetic failures: no effect was achieved after waiting 10 minutes following infiltration of the anesthetic solution. Onset of lip numbness in this group was found to be 3.8 minutes, a significant difference (p<0.05) from the conventional technique. The mean age of subjects in this group was 23.3 years of age and the anesthetic solution administered was 1.8 mL 4% articaine with 1:100,000 epinephrine. The authors note that when defining anesthetic failure as the existence of pain during the extraction procedure or the impossibility of eliciting an anesthetic effect, 3 of the 28 conventional blocks failed (10.7%) versus 5 of the 28 Akinosi infiltrations (17.8%) (88). Gonzalez’s group concluded that though the Akinosi technique is useful for mandibular anesthesia, the conventional technique “offers superior anesthetic performance” (88).

Goldberg et al. (23), in asymptomatic vital teeth, found the ranges of successful pulpal anesthesia were as follows: 25% to 62% (inferior alveolar technique), 13% to 50%
(Vazirani-Akinosi technique). There was no significant difference (p>0.05) in success among the two techniques. A volume of 3.6 mL of 2% lidocaine with 1:100,000 epinephrine were used with 40 subjects participating in a cross-over design in which each subject randomly received three different injections (conventional inferior alveolar, Gow-Gates, and Vazirani-Akinosi) spaced at least 1 week apart. Ten Vazirani-Akinosi injections (25%) did not have profound lip numbness at 21 minutes, indicating that the block was unsuccessful (a missed block) and these ten injections were eliminated from statistical analysis. Only subjects achieving lip numbness within 21 minutes were utilized for statistical comparison. An electric pulp tester was utilized on the first molars, first premolars, and lateral incisors with the contralateral canine used as the unanesthetized control to ensure proper function of the pulp tester and the subject’s appropriate response. Despite no significant difference in the success of pulpal anesthesia (2 consecutive 80 readings within 15 minutes of the injection and the 80 reading sustained through the 60th minute) between the conventional and Vazirani-Akinosi techniques, the Vazirani-Akinosi technique resulted in a statistically slower onset of pulpal anesthesia than the inferior alveolar nerve block. Onset was defined as the first of 2 consecutive 80 readings (23).

Comparison of mean onset times (in minutes) for the conventional versus Akinosi techniques, respectively: first molar 8+/5.8 versus 18+/12.1, first premolar 7+/4.4 versus 16+/11.4, and lateral incisor 12+/5.5 versus 18+/8.8 (23).
Irreversible Pulpitis with the Vazirani-Akinosi and Gow-Gates Injections

In patients with irreversible pulpitis, Sherman et al. (89) compared 4% articaine with 1:100,000 epinephrine and 2% lidocaine with 1:100,000 epinephrine using the Gow-Gates technique in posterior teeth. Subjects rated their initial pain on a VAS and were given either 1.7 mL of 4% articaine with 1:100,000 epinephrine or 1.8 mL of 2% lidocaine with 1:100,000 epinephrine for a Gow-Gates or maxillary infiltration as appropriate for their symptomatic tooth. The operator was blinded as to which anesthetic solution was used on each subject. The block was considered successful if the subject’s tooth was accessed with a pain rating no greater than mild pain (greater than 0 mm but less than 54 mm). Anesthetic success was achieved in 87.5% of all patients who qualified for treatment, four anesthetic failures were observed in the mandibular arch and one in the maxillary arch. However, the authors found no observable correlation between anesthetic type and failure or tooth arch and failure. While the authors found no difference between the two anesthetic formulations, the study only used 10 subjects per group. The number of patients in each group would have to be higher to reach clinical conclusions.

Aggarwal et al. (90) found the Gow-Gates technique improved success over the conventional inferior alveolar nerve block in patients with irreversible pulpitis. The success rates were 52% and 36% respectively (90-Aggarwal). The Vazirani-Akinosi technique had a success rate of 41% (90). The numbers in each group of patients were small with twenty-four receiving Vazirani-Akinosi blocks, twenty-five receiving Gow-Gates blocks, twenty-two receiving the control – a conventional inferior alveolar block,
and twenty-six receiving a buccal-plus-lingual infiltration. These small group numbers may have affected the results.

Further study of the Gow-Gates and Vazirani-Akinosi techniques are needed in patients presenting with irreversible pulpitis. The purpose of this prospective, randomized study was to evaluate the degree of pulpal anesthesia obtained with the Gow-Gates and Vazirani-Akinosi techniques using 3.6 mL of 2% lidocaine with 1:100,000 epinephrine in patients presenting with symptomatic, irreversible pulpitis. The pain of the injections was also assessed.
CHAPTER 2
MATERIALS AND METHODS

Approval for this study was granted by the Ohio State University Human Subjects Review Committee. Adult emergency patients of the College of Dentistry, ages 18 years or older, participated in this study. All were in good health as determined by a health history and oral questioning (ASA Class I or II). Reasons for exclusion from the study were as follows: allergy or contraindication to local anesthetic agents; ASA classification III or greater; taken CNS depressants within the last 6 hours; pregnancy; lactating; or inability to give informed consent. Each patient had a vital mandibular posterior tooth (molar or premolar), was actively experiencing pain, and had a prolonged response to cold testing with Endo-Ice® (1,1,1,2 tetrafluoroethane; Hygenic Corp., Akron OH) to qualify for the study. Patients with no response to cold testing, periradicular pathosis (other than a widened periodontal ligament), or no vital coronal pulp tissue upon access were excluded from the study. Through the course of the study, 2 patients of 127 included were found to have necrotic coronal pulp tissue upon access and were excluded from the study (Figure 1). Each patient had a tooth that fulfilled the criteria for a clinical diagnosis of symptomatic irreversible pulpitis. If the patient met all inclusion criteria, they were asked to sign a HIPAA form. Informed consent was obtained. Patients
completed the Corah’s Dental Anxiety Scale questionnaire (Appendix E, 91-93). Patients also rated their initial pain on a Heft Parker visual analog scale (VAS) (94). The VAS was divided into four categories (Appendix F). No pain corresponded to 0 mm. Mild pain was defined as greater than 0 mm and less than or equal to 54 mm. Mild pain included the descriptors of “faint”, “weak”, and “mild” pain. Moderate pain was defined as greater than 54 mm and less than 114 mm and included the descriptor “moderate”. Severe pain was defined as equal to or greater than 114 mm. Severe pain included the descriptors of “strong”, “intense” and “maximum possible”. The patient needed to mark their initial pain as moderate-to-severe on the VAS for inclusion in the study.

![Figure 1. Study Enrollment]

*Included in pulpal anesthesia data analysis
Grey box indicates not analyzed in Tables section
The patients randomly received either a Gow-Gates or Vazirani-Akinosi nerve block. A list of six-digit numbers corresponding to each potential study patient was randomly assigned to 60 Gow-Gates injections and 60 Vazirani-Akinosi injections by computer randomization completed via www.random.org. Until the patient signed the informed consent; neither the operator, nor patient was aware of which injection was to be used. After informed consent was obtained, the operator checked the next number on the master list and administered the injection associated with that patient’s randomly generated six-digit number.

A total of 3.6 mL of 2% lidocaine with 1:100,000 epinephrine (Xylocaine, AstraZeneca LP, Dentsply, York, PA) was loaded into a sterile 5 mL Luer-Lok syringe (Becton, Dickinson and Co., Rutherford, NJ) using standard anesthetic cartridges. The cartridges were checked to ensure that the anesthetic solutions were not expired. The anesthetic cartridges were placed into a standard dental syringe and expressed into the sterile 5 mL Luer-Lok syringe via a 30-gauge short needle (Monoject; Sherwood Medical, St. Louis MO). The solution level in the Luer-Lok syringe was checked to confirm that 3.6 mL of 2% lidocaine with 1:100,000 epinephrine were present, without air bubbles. If the solution level was below the 3.6 mL mark, additional 2% lidocaine with 1:100,000 epinephrine was added to the Luer-Lok syringe in the method described above. If the solution level was above the 3.6 mL mark, solution was expressed until the solution volume corresponded exactly with the 3.6 mL mark on the Luer-Lok syringe. The needle used for all injections was a 27-gauge 1½-inch (38.1 mm) needle (Monoject; Sherwood Medical, St. Louis, MO). Topical anesthetic gel (20% benzocaine, Patterson
Dental Supply, Inc., St. Paul, MN) was passively placed at all block injection sites for 60 seconds using a cotton tip applicator.

The Gow-Gates nerve block was administered as described by Gow-Gates (71). The patient was placed in the supine position, with the neck extended and the mouth open as wide as possible. A finger was placed on the external auditory meatus on the side of the injection to identify this extra-oral landmark. The cheek was retracted laterally. The injection site was just distal to the maxillary second molar, at a height established by the mesiolingual cusp of that tooth. The syringe was directed from the corner of the mouth on the contralateral side, toward the ipsilateral ear. The needle was situated in a plane extending from the ear to the corner of the mouth on the ipsilateral side and was parallel to the angle created by the ear and the side of the face. The needle penetrated the mucosa (needle insertion) and was then advanced slowly (needle placement) until anterolateral contact was made with the neck of the condyle, or until a depth of penetration of approximately 25 mm was reached (71, 73, 74, 80). The operator approximated a 25 mm depth of insertion by observing the remaining portion of the needle, not inserted into the mucosa, at approximately 10-15 mm. If contact was not made with the neck of the condyle on the initial attempt, the needle was withdrawn slightly and the needle was redirected at a different angle. A concerted effort was made to contact the neck of the condyle. In two subjects, the condyle was contacted at 8 mm and 10 mm, respectively. The operator determined these values once administration of the injection was completed by measuring the needle with a periodontal probe to the estimated depth of insertion observed. The patient with a 10 mm depth of insertion achieved subjective lip numbness. The patient in whom 8 mm depth of insertion was noted upon injection administration did
not achieve subjective lip numbness. In total, one subject in 65 subjects who received the Gow-Gates injection failed to attain lip numbness in conjunction with a short depth of insertion. For all other 63 Gow-Gates injections, an average range of insertion depth was 22-25 mm. After contact with the condyle, the needle was withdrawn 1 mm, aspiration performed, and the anesthetic solution was deposited over a period of two minutes (solution deposition). Following the injection, the subject was asked to keep his/her mouth wide open for 60 seconds, as measured by the operatory clock.

The Vazirani-Akinosi nerve block was administered as described by Akinosi (82), Vazirani (83) and Gustainis and Peterson (84). The subject was placed in a supine position and asked to bring their teeth into occlusion or the rest position, with the muscles of mastication relaxed. A cotton roll was placed under the ipsilateral upper lip in order to facilitate visualization of the insertion site. The cheek was retracted laterally with a dental mirror, allowing the edge of the mirror to rest on the anterior border of the ramus. The injection site was the soft tissue overlying the medial surface of the ramus, adjacent to the maxillary tuberosity, at a height established by the mucogingival junction in the area of the maxillary second molar. The needle was bent 45 degrees towards the needle bevel at approximately 3 mm from its hub. The needle was bent so as to facilitate the placement of the needle tip as close as possible to the inferior alveolar nerve within the pterygomandibular space, on the medial aspect of the mandibular ramus. Consequently, upon insertion the needle bevel was oriented toward the medial aspect of the mandibular ramus. The needle penetrated the mucosa at the injection site (needle insertion) and was directed postero-laterally until the barrel of the syringe was positioned parallel to the ipsilateral maxillary alveolus (placement). The barrel of the syringe was consistently
kept on a plane parallel to the maxillary mucogingival junction and occlusal plane, landmarks described by Vazirani (83) and Akinosi (82). All 60 Vazirani-Akinosi injections were inserted to a depth of 30-35 mm. As the needle was 38.1 mm, the operator observed insertion to a point approximately 5 mm from the hub of the needle. Aspiration was performed and the anesthetic solution was deposited over a period of two minutes (solution deposition). All injections were given by the senior author (VC). The senior author utilized the two injection techniques (Gow-Gates and Vazirani-Akinosi) in a clinical setting for two months before initiation of the study. To confirm correct technique, the author injected a volunteer member of the OSU Advanced Endodontics Program under the supervision of an attending endodontist 5 times (once per week) prior to initializing the study and monitored him/her for lip numbness at 10 and 20 minutes post-injection to confirm consistent technique.

For both injection techniques, a separate buccal nerve block was administered using a standard syringe and 2% lidocaine with 1:100,000 epinephrine when indicated. A half cartridge volume (0.9 mL) was used for the buccal nerve block technique (6).

The patient was questioned at 10 minutes post-injection and again at 20 minutes whether his/her lip was numb. If profound lip numbness was not recorded at 20 minutes, the Gow-Gates block was considered missed and the patient was dismissed from the study. If profound lip numbness was not recorded at 20 minutes, the Vazirani-Akinosi patients were given an extra 5-minute waiting period. Both the Gow-Gates and Vazirani-Akinosi injections are shown to have longer onset times than the traditional inferior alveolar block (77, 79, 23, 88), therefore the 20-minute period was utilized for Gow-Gates and Vazirani-Akinosi subjects. The onset time for the Gow-Gates injection is
reported to be 5-7 min by Malamed (6, 75), 7.68 min by Sisk (77), and 7 min on average by Todorovic et al. (79), in whose study a range of 1-20 minutes was noted. Goldberg et al. described a mean onset time of 17 minutes (23). In light of these findings, this study used 20 minutes as an onset time for lip anesthesia and initiation of endodontic access.

As the study progressed, it became evident that a high number of Vazirani-Akinosi subjects were not experiencing subjective lip numbness at 20 minutes. Potentially, a slow anesthetic onset was cause for the lack of subjective lip numbness at 20 minutes. An additional 5-minute waiting period was given to subjects receiving the Vazirani-Akinosi injection to take into account slow onset. Yücel et al. noted only 51% of his subjects experienced anesthetic onset at 5 minutes (87). Goldberg et al., found a mean onset time of 18 minutes (23).

At 25 minutes the patients receiving the Vazirani-Akinosi injection were questioned again; if the lip was numb at either 20 or 25 minutes, the Vazirani-Akinosi block was considered successful. If at 25 minutes no lip numbness was achieved, the Vazirani-Akinosi block was recorded as a failure and included as such in the study. Patients continuing within the study (Gow-Gates lip numbness after 20 minutes, Vazirani-Akinosi lip numbness after 25 minutes) received continued treatment for endodontic therapy. Patients disqualified from the study due to lack of lip numbness received a conventional inferior alveolar nerve block and any supplemental anesthesia required to complete emergency root canal treatment.

At 20 or 25 minutes post-injection depending on which injection was utilized, the tooth was isolated with a rubber dam and endodontic access was performed. Of 38 total subjects analyzed in the Vazirani-Akinosi group 33 subjects achieved subjective lip
numbness by 20 minutes, 3 subjects achieved subjective lip numbness at 25 minutes when none was noted at the 20-minute mark. For the remaining two subjects’ treatment was initiated at 30 minutes and 35 minutes post-injection due to scheduling delay in the clinic. Patients were instructed to definitively rate any pain felt during the endodontic procedure. If the patient felt pain, the treatment was immediately stopped and the patient rated their discomfort using the Heft-Parker visual analog scale (94). If the pain rating was mild, treatment continued. If the pain rating was moderate or greater, supplemental anesthesia was administered. The extent of access achieved when the patient felt pain was recorded as within dentin, entering the pulp chamber, or initial file placement. The success of the two nerve blocks was defined as the ability to access and instrument the tooth without pain (VAS score of zero) or mild pain (VAS rating less than or equal to 54 mm).

If the patient experienced moderate to severe pain (55 mm or higher on the VAS) during treatment, supplemental anesthetic was given to complete emergency endodontic treatment. First, the rubber dam was removed and one cartridge of 4% articaine 1:100,000 epinephrine was given as a buccal infiltration over 1 minute at the site of the emergency tooth’s approximated root apices. The patient was instructed to complete a VAS corresponding to pain felt during the buccal infiltration related to three stages: needle insertion, needle placement, and 1-minute anesthetic deposition. After 5 minutes elapsed to allow for sufficient anesthesia (95) the rubber dam was replaced and endodontic treatment resumed. If the patient felt no pain or mild pain, treatment continued. If the patient felt moderate to severe pain (55 mm or higher on the VAS), treatment was again stopped and the level of access noted: dentin, pulp chamber, or
canal instrumentation. The success of the buccal infiltration was defined as the ability to access and instrument the tooth with no or mild pain (VAS score of zero or less than or equal to 54 mm, respectively).

If the buccal infiltration was unsuccessful, an intraosseous injection was administered after removal of the rubber dam. A volume of 1.8 mL of 2% lidocaine 1:100,000 epinephrine was utilized with the Stabident intraosseous anesthetic delivery system (Fairfax Dental Inc., Miami, FL) as described by a previous study (66). The rubber dam was replaced and treatment continued. If moderate to severe pain was felt again (VAS rating greater than 54 mm), the intraosseous injection was repeated. If moderate to severe pain was felt again, intrapulpal injections were administered using 2% lidocaine with 1:100,000 epinephrine. Patients who received the intrapulpal injection had achieved sufficient anesthesia at this point in their treatment to unroof the pulpal chamber, thereby allowing the administration of the intrapulpal injection. All patients who received the intrapulpal injection did not require any additional anesthesia to complete root canal treatment. Two patients received intraligamentary injections. The first received an intraligamentary (IL) injection following a failed buccal infiltration instead of an intraosseous injection. An intraosseous injection was attempted on this patient but was too painful to administer. The IL injection provided adequate anesthesia for this subject to complete emergency root canal therapy during the appointment. The second patient who received an IL injection had received an intraosseous injection mesially (tooth #18) and then experienced moderate to severe pain during access. A distal intraosseous injection for tooth #18 was not possible given the patient’s intraoral anatomical space constraints. At this point, the access was still in dentin so an IL
injection was administered. This allowed access into the pulpal chamber, at which time an intrapulpal injection was administered resulting in successful pulpal anesthesia and completion of emergency root canal treatment.

Root canals were cleaned and shaped with hand and rotary instruments, using K-type hand files and ProFile GT® or Vortex® rotary instruments. Oral post-operative instructions were given when treatment was completed and pain management prescriptions were supplied as indicated. If the patient requested an extraction rather than emergency endodontic treatment, access and canal instrumentation were completed and then the tooth was extracted in a different clinic.

Patients were asked if they recalled pain during treatment and then were asked to mark another VAS (0-170 mm) corresponding to the greatest amount of intraoperative pain remembered. Patients rated the degree of satisfaction they experienced during endodontic treatment on a 100 mm visual analog scale (Appendix G). The VAS was divided into four categories. Not satisfied corresponded to 0 mm. Somewhat satisfied was defined as greater than 0 mm and less than or equal to 33 mm. Moderately satisfied was defined as greater than 33 mm and less than 66 mm. Completely satisfied was defined as equal to or greater than 66 mm. The principal investigator explained the use of the VAS and that responses would not affect the operator’s grades or reviews, and then left the operatory. The patient completed the VAS, enclosed it in an envelope and turned it in to another provider not involved in the study. Patients were reappointed for completion of root canal therapy at a later date or referred for extraction of the tooth as appropriate. The patient then received $75.00 cash for their participation.
The data from this study were collected and statistically analyzed. Comparisons between the Gow-Gates and Varizani-Akinosi techniques for anesthetic success and failure were made using multiple chi-square tests with p-values adjusted using the step-down method of Holm. Differences between the anesthetic formulations for initial pain, needle insertion pain, needle placement pain, solution deposition pain, and anxiety were assessed using analysis of variance.

With a non-directional alpha risk of 0.05 and assuming null success rate of 35% (23, 45) a sample size of 60 subjects per group was required to demonstrate a difference of ± 25 percentage points in anesthetic success with a power of 0.82. With a non-directional alpha risk of 0.05 and assuming a standard deviation of 34.0, a sample size of 60 subjects per group would provide a power of 0.84 to demonstrate a difference ± 20 points on the visual analogue scale.
CHAPTER 3
RESULTS

Ninety-eight subjects were analyzed in this study. Sixty subjects who received a Gow-Gates injection were analyzed and 38 subjects who received a Vazirani-Akinosi injection were analyzed (Table 1). In the Gow-Gates group, the mean age of participating patients was 33.5 ± 10.6 years, while the mean age of the patients in the Vazirani-Akinosi group was 34.3 ± 10.2 years. There were 43 female subjects included in the Gow-Gates group, with the remaining 17 subjects being male. In the Vazirani-Akinosi group, 21 subjects were female and 17 were male. No statistically significant differences were found between females receiving either the Gow-Gates or Vazirani-Akinosi injection, or between males receiving either the Gow-Gates or Vazirani-Akinosi injection (Table 1). To qualify for this study, patients had to present with moderate-to-severe pain as defined on a 170 mm Heft-Parker Visual Analog Scale (VAS). The mean initial pain experienced by patients in the Gow-Gates group was 117.3 ± 22.1 mm, and 119.1 ± 27.4 mm for patients in the Vazirani-Akinosi group. There was no statistically significant difference noted between these two groups (Table 1).

Results from Corah’s Dental Anxiety Scale, which every subject completed before treatment began, are shown in Table 2. A score between 4 and 20 was possible with lower numbers indicating less anxiety and higher numbers indicating more anxiety.
The mean score in the Gow-Gates group was 9.0 ± 4.0. In the Vazirani-Group the mean score was 10.5 ± 4.1. No statistically significant difference was found between the two groups.

Table 3 illustrates the tooth type treated in this study per group. The majority of teeth treated in this study were molars, particularly 1st molars, with only 2 premolars treated in the Gow-Gates injection group and 0 in the Vazirani-Akinosi group. There was no statistically significant difference found in tooth type between the two groups. There was also no statistically significant difference noted in the number of males or females per group in this study (Table 3).

Block success, or the experience of subjective lip numbness, is shown in Table 4. Of the 65 total subjects that received a Gow-Gates injection, 60 experienced subjective lip numbness, or block success, 92% of the time. In contrast, 63% of subjects receiving the Vazirani-Akinosi injection (38 of 60 total subjects) experienced subjective lip numbness, or block success. Pulpal anesthetic success of the two block injections is also shown in this table.

Table 5 analyzes the pulpal anesthetic success of the two block injections, articaine infiltration, and intraosseous injections administered to both Gow-Gates and Vazirani-Akinosi groups following failure of the initial study injections. Pulpal anesthesia was obtained in 21 of 60 subjects, or 35%, of the Gow-Gates group from that injection alone. The Vazirani-Akinosi injection yielded a 16% pulpal anesthesia success rate, or 6 of 38 subjects. A statistically significant difference was noted between these two groups (Table 4 and 5). In the Gow-Gates group, the 39 subjects who did not achieve successful pulpal anesthesia, defined by the study as complete access and
instrumentation of the tooth without pain (a VAS score of zero) or mild pain (a VAS score less than or equal to 54 mm), were given a buccal infiltration of 1.8 mL of 4% articaine with 1:100,000 epinephrine. The 32 subjects in the Vazirani-Akinosi group who did not achieve pulpal anesthetic success with this injection were also given the same buccal infiltration for supplemental anesthesia. Of these remaining subjects, 20 (51%) in the Gow-Gates group and 12 (38%) in the Vazirani-Akinosi group achieved successful pulpal anesthesia from the buccal infiltration. For those subjects requiring additional anesthesia, an intraosseous (IO#1) injection was administered. Fourteen (74%) in the Gow-Gates group and 11 (58%) in the Vazirani-Akinosi group achieved successful anesthesia with this supplemental technique. Remaining subjects were given a second intraosseous injection (IO#2). Three (75%) subjects in the Gow-Gates group and 2 (29%) in the Vazirani-Akinosi group attained successful pulpal anesthesia with the second intraosseous injection. The remaining patients, one in the Gow-Gates group and five in the Vazirani-Akinosi group were able to complete the study with the administration of an intrapulpal injection. By the time the second intraosseous injection was administered, the operator was able to unroof the pulpal chamber allowing application of the intrapulpal technique. There was no occasion in which a subject was not able to complete the study.

In Table 6, the pulpal anesthetic success of the block injections, Gow-Gates and Vazirani-Akinosi, are evaluated by gender. In female subjects, the Gow-Gates injection produced a 40% pulpal anesthesia success rate while the Vazirani-Akinosi injection produced a 10% success rate. A statistically significant difference was noted between these two groups (Table 6). In male subjects, the pulpal anesthetic success rate was 24%
for both groups. No statistically significant difference was found between the two male groups.

The pain of the injections was rated on a 170 mm VAS at three stages, cued orally by the operator. These stages were insertion, placement, and deposition. Table 7 reviews the pain of the Gow-Gates and Vazirani-Akinosi injections. No statistically significant differences were noted between the experienced pain of the two injection techniques. Table 8 reviews the injection pain by stage by gender. Again, no statistically significant differences were noted between the two groups.

Table 9 shows the pain of the Gow-Gates and Vazirani-Akinosi injections by stage using the categorical descriptors of the 170 mm VAS. In the Gow-Gates group, most subjects (58%) felt mild pain (greater than 0 mm and less than or equal to 54 mm) upon insertion, and moderate pain (greater than 54 mm and less than 114 mm) for placement (53%) and deposition (57%) stages. Similarly, in the Vazirani-Akinosi group, most subjects (55%) also felt mild pain during insertion and moderate pain during placement (39%) and deposition (53%) stages. No statistically significant differences were found among pain felt in these stages.

Table 10 illustrates the stage at which moderate to severe pain was felt during treatment, or the point of failure. The majority of the failures were experienced in the dentin after the block and articaine injections. After the first intraosseous injections, the majority of pain felt in the Vazirani-Akinosi group was in dentin, while equivalent numbers experienced anesthetic failure in dentin and during canal instrumentation in the Gow-Gates group. After administration of the second intraosseous injection, pain in both
groups was experienced either in the dentin or once the chamber was entered by the operator.

Table 11 describes the patients’ post-treatment remembered pain, or the maximum pain the patient recalled experiencing throughout the period of treatment. Using the 170 mm VAS, the majority of patients in the Gow-Gates and Vazirani-Akinosi groups noted mild-to-moderate pain as their maximum experienced pain. No statistically significant difference was noted between the two groups.

Patients were asked to complete a 100 mm satisfaction scale upon completion of the study. Post-treatment satisfaction ratings are presented in Table 12. All patients in the Gow-Gates group reported at least moderate satisfaction with the majority (95%) noting complete satisfaction as defined by the scale. In the Vazirani-Akinosi group, the majority of patients noted at least moderate satisfaction with 94% stating complete satisfaction. Only one patient in the study, from the Vazirani-Akinosi group, recorded a 0 mm mark denoting he was not satisfied with treatment. He explained that he marked the scale at this point because he was having his tooth extracted and not completing endodontic therapy with the operator.
CHAPTER 4
DISCUSSION

The purpose of this study was to evaluate the degree of pulpal anesthesia obtained with the Gow-Gates and Vazirani-Akinosi techniques using 3.6 mL of 2% lidocaine with 1:100,000 epinephrine in patients presenting with symptomatic irreversible pulpitis.

Table 1 demonstrates the number of patients participating in this study, 60 in the Gow-Gates group and 38 in the Vazirani-Akinosi group. Between the two groups, no statistical difference was noted among the variables of age, gender, or initial pain. In order to qualify for the study, patients had to present with moderate to severe initial pain as reported on a 170 mm VAS. It is important to have patients begin from a comparable baseline of pain in order to evaluate anesthetic effects between the two groups. In patients diagnosed with symptomatic irreversible pulpitis, the effects of the inflammatory process taking place within the nervous tissue of their teeth may significantly affect their perception of pain. Cytokine release enhances the excitability of nociceptor isoforms resulting in lowered thresholds for pain and therefore increased experience of pain (38, 96). Importantly, the experience of preoperative pain resulting from symptomatic irreversible pulpitis affects the success rate of the conventional IANB (45, 54, 55, 57, 59, 60, 62, 65, 90, 96) so it would be expected that this would also hold true for alternative...
IANB techniques, namely the Gow-Gates and Vazirani-Akinosi techniques. If one group presented with higher initial pain scores than the other, the results of this study could be biased. The mean initial pain reported by the Gow-Gates group was $117.3 \pm 22.1$ mm and the Vazirani-Akinosi group reported a mean initial pain value of $119.1 \pm 27.4$ mm on the VAS. These values do not show a statistically significantly difference therefore any differences among our study’s results was minimized.

In our investigation, no significant difference was noted between the two technique groups concerning age (Table 1). It is believed that a difference in pain perception to acute noxious stimuli is related to age (97). In evaluating an older (mean age of 62 years) and a younger (mean age of 22 years) group of subjects’ responses to various noxious stimuli, they noted a significant difference in ischemic pain but no significant differences between the groups in response to thermal or mechanical noxious stimuli. Harkins and Chapman’s work on pain perception and age using electric pulp testing on dentition concluded that pain differences may be due to a response bias (98, 99). The authors found that at low levels of electric current to the tooth’s pulp, older patients are more reluctant to call the stimulation painful, but at higher levels this group is significantly more willing than their younger counterparts in labeling the stimulus as painful (98, 99). If one group presented with a significantly older age range than the other, our data may have been skewed. That was not the case in this study, as the mean age in the Gow-Gates group was $33.5 \pm 10.6$ years while the mean age in the Vazirani-Akinosi group was $34.3 \pm 10.2$ years.

Another confounding variable associated with our study was gender of the subjects. A recent systematic review evaluating 10 years of research on gender-related
differences in pain perception provided mixed results. Though the majority of reviewed studies measuring pain intensity and unpleasantness showed no significant differences among males and females, a break down of various laboratory tests measuring thermal, pressure, ischemic, muscle, electrical, chemical and visceral pain in healthy subjects showed some evidence for gender-related differences. The review noted similar pain thresholds among males and females in cold and ischemic pain while pain thresholds in pressure tests were lower in females than males. The review notes that it appears evident that despite a decade of laboratory research on the subject, there is no concise or reliable pattern of sex differences in human pain sensitivity (100). No statistically significant difference was noted among the gender of the subjects in our study therefore gender-associated statistical alteration of our results was reduced.

Table 2 demonstrates the subjects’ self-evaluation of their pre-operative anxiety as defined by a Corah Dental Anxiety Scale questionnaire (91, 92). Anxiety of the patient adds another layer of complexity into an already multidimensional process of pain perception and analysis. It is valuable to observe the range of anxiety scores in the two groups assessed in this study. Patients were asked to complete the Corah questionnaire, which consisted of four questions describing four different dental scenarios. Each question had five possible answers labeled A, B, C, D, or E with A tabulated as 1 point and E as 5 points. A minimum score of 4 defined a relaxed patient and a maximum score of 20 defined a very anxious patient (91, 92). No statistically significant difference was noted among the two groups (p = 0.3007) or in males versus females among either of the two groups (p = 0.8081 for males and p = 0.1097 for females). This finding allowed our study to minimize a possible interaction between pre-operative anxiety levels and pain
values reported during treatment.

In their study evaluating the effects of nitrous oxide on the efficacy of the conventional IANB in patients with symptomatic irreversible pulpitis, Stanley et al. noted no difference (p = 1.000) in the Corah scores of their nitrous oxide group (11 ± 4) and placebo group (11 ± 4) (66). Simpson et al. noted anxiety scores of 10 ± 3 in their ibuprofen/acetaminophen pretreatment group and 9 ± 3 in their placebo group (p = 0.508) in their investigation of the effects of premedication on the efficacy of the conventional IANB in patients with symptomatic irreversible pulpitis (44). Our investigation was commensurate with these similarly designed previous studies; Corah scores for the Gow-Gates injection were 9.0 ± 4.0 and 10.5 ± 4.1 for the Vazirani-Akinosi group.

Table 3 indicates the identification of tooth types treated in this study. It is valuable to have a random sampling of teeth treated in this study so as not to potentially influence results. If one group of subjects were treated primarily for second molars and the other for first premolars, there may be some bias in anesthetic success since premolars are shown to have a slightly higher incidence of pulpal anesthesia following a conventional IANB injection of 2% lidocaine with 1:100,000 epinephrine (38). Our study found no statistically significant difference (p = 0.5850) in tooth types undergoing treatment. Table 3 also illustrates that there was no significant difference found among the number of evaluated males and females receiving either the Gow-Gates or the Vazirani-Akinosi injection (p = 0.0965), though it is interesting to note that in both technique groups, male subjects randomly accounted for 17 subjects of the total.

Table 4 illustrates the block success, measured by subjective lip numbness, of the Gow-Gates and Vazirani-Akinosi injection techniques. The Gow-Gates injection was
successful in effecting subjective lip numbness in 60 out of 65 subjects (92%) whereas the Vazirani-Akinosi injection produced subjective lip numbness in 38 out of 60 (63%) of subjects. In reviewing historical controls evaluating the conventional inferior alveolar block injection, or IANB, lip numbness occurs 87% to 91% of the time (37). Notably, Simon and co-authors found no significant difference in procurement of lip numbness between a conventionally administered IANB and an IANB administered with the aid of a peripheral nerve stimulator, a device used to insure accurate placement close to the inferior alveolar nerve. Simon’s study included subjects with healthy, vital teeth, however success rates for lip numbness were similar even in patients diagnosed with symptomatic irreversible pulpitis. In Fullmer’s study of symptomatic irreversible pulpitis patients, he noted an IANB lip success rate of 90%. (48). It appears from our data that the Vazirani-Akinosi technique was clinically inferior to the IANB and Gow-Gates techniques for routine endodontic treatment because it did not result in lip numbness with the same consistency as the latter two techniques. Subjective lip numbness is an important signal in that its absence indicates an inaccurate block, i.e. failed anesthetic effects on the inferior alveolar nerve (38).

As the study progressed, it became clear that the Vazirani-Akinosi had a higher failure rate than the Gow-Gates or conventional IANB. Subjective lip numbness was not consistently achieved despite calibration of the operator. Therefore, it was important to note how many lip numbness failures resulted from the Vazirani-Akinosi technique and include these subjects in our data. As a result, the data analyzed with regard to pulpal anesthesia is drawn from two differing sample sizes: 60 patients in the Gow-Gates group and 38 patients in the Vazirani-Akinosi group. Sixty patients were administered the
Vazirani-Akinosi injection, but only 38 (63%) achieved lip numbness. These remaining 38 subjects continued with endodontic treatment provided as per this study’s protocol. The 22 subjects experiencing no subjective lip numbness were given a conventional IANB and did not continue with endodontic treatment until subjective lip numbness was achieved. All 22 subjects that did not achieve lip numbness with the Vazirani-Akinosi injection did experience lip numbness with the conventional IANB. This indicates that these subjects were not likely patients that experienced difficulty in achieving lip numbness due to slow onset anesthesia. Despite no lip numbness achieved with the Vazirani-Akinosi, the IANB in these 22 subjects generated lip numbness 100% of the time, suggesting that the conventional IANB is a better injection technique than the Vazirani-Akinosi technique. It is possible that some patients’ anatomical differences provide an explanation for the failed block success of the Vazirani-Akinosi injection. This technique employs limited landmarks; unlike the conventional IANB and the Gow-Gates techniques in which bone can be sounded by the needle near the target site, the only indications of correct target placement in the Vazirani-Akinosi technique is the depth of insertion and initial needle orientation. It is conceivable, due to variations in human condylar angles as well as the unpredictable movement of deposited anesthetic solution in a given anatomical space, that the site of solution deposition or spread of the deposited solution in patients who did not achieve successful lip numbness with the Vazirani-Akinosi injection was the cause for block failure despite consistent operator technique.

An argument may be made regarding operator error, that despite calibration, the operator did not know how to accurately administer the Vazirani-Akinosi technique.
This seems unlikely given that the operator spent 2 months calibrating herself to the technique, but even if operator error is at fault, the fact that this technique may be so difficult to master even after calibration attests to its difficulty and resulting clinical unreliability.

It is important to note that despite failed lip numbness, all patients who received the Vazirani-Akinosi injection experienced numbness in the ipsilateral cheek and temporal mandibular joint (TMJ) area. This is not an unusual finding in that the Vazirani-Akinosi injection is most commonly used in patients experiencing trismus and is in fact indicated for such cases (6, 82-84). Though our investigation appears to show that this technique is not indicated for routine endodontic treatment, it certainly has useful indications elsewhere in dentistry. For example, if a patient experiencing trismus is in need of an extraction, endodontic, or restorative treatment, the Vazirani-Akinosi injection may be a useful primary anesthetic technique. The muscles of mastication protectively guard painful mouth opening in patients with buccal or TMJ swelling. An injection technique such as the Vazirani-Akinosi that does not require any mouth opening for administration can result in facilitated mouth opening due to anesthesia of the ipsilateral muscles of mastication. Now that this increased opening is achieved, a conventional IANB may be administered to the trismus patient.

As our study found a significant number of lip numbness failures resulting from the Vazirani-Akinosi subject group, we could compare the Vazirani-Akinosi and Gow-Gates techniques against historical controls. Instead of directly comparing the pulpal anesthetic results in symptomatic irreversible pulpitis patients receiving either the Gow-Gates or Vazirani-Akinosi injections, our study evaluated the pulpal anesthetic success
rate of the successfully blocked patients in the Gow-Gates group and Vazirani-Akinosi groups against historical controls of the conventional IANB in patients with symptomatic irreversible pulpitis. As mentioned above, our study’s sample size for the Vazirani-Akinosi group was lower than that of the Gow-Gates group, 38 to 60 subjects, respectively. Due to the high block failure rate of the Vazirani-Akinosi injection, this injection is not recommended for routine endodontic care. For this reason, our research group chose to discontinue exposure of study patients to this injection in order to determine a pulpal anesthetic rate. As a result, our sample size of Vazirani-Akinosi subjects is lower than the sample size required by our study’s power analysis. Because this investigation’s Vazirani-Akinosi group is underpowered, we cannot confirm or validate a pulpal anesthetic success rate for the Vazirani-Akinosi injection technique. If the administration of a successful Vazirani-Akinosi injection resulted in a dramatically higher pulpal anesthesia rate than the Gow-Gates or the conventional IANB, then the high block failure rate may be acceptable; however, this was not the case in our investigation.

Differences in block success could be attributed to onset times, volume of anesthetic solution, and depth of insertion. As a baseline, studies evaluating the IANB reveal that successful lip numbness occurs in 4.5 to 6 minutes. Wali et al. noted a 4.4 ± 0.4 minute onset of subjective lip numbness as confirmed by questioning the patient every minute post-IANB injection of 1.8 mL 2% lidocaine with 1:100,000 epinephrine (3). Vreeland et al. found that patient response to questioning concerning subjective lip numbness once every minute post-injection was positive at 6.70 ± 0.757 and 8.80 ± 1.290 minutes for injections using 1.8 mL and 3.6 mL of 2% lidocaine with 1:100,000
epinephrine, respectively (4). Hinkley et al., using the same questioning technique, found a mean onset of lip anesthesia for a block utilizing 1.8 mL 2% lidocaine with 1:100,000 epinephrine to be at 6.1 ± 0.8 minutes (7). McLean et al. noted a 5.0 ± 0.65 minute patient response to query concerning lip numbness after a IANB of 1.8 mL 2% lidocaine with 1:100,000 epinephrine (8). Chaney et al. found patient response to be in the affirmative (indicating subjective lip numbness) at a mean of 4.7 ± 0.4 minutes after an IANB of 1.8 mL 2% lidocaine with 1:100,000 epinephrine (12). In summary, Reader and co-authors note an overall range of 4.5 to 6 minutes for successful lip numbness achieved via the conventional IANB (38).

The Gow-Gates injection is reported to produce subjective numbness, or onset, in a range from one to 45 minutes (6, 22, 23, 71, 74, 75, 77, 79, 80, 81). Malamed noted an onset within 5-7 minutes using a 1.8 mL volume of 2% lidocaine with 1:100,000 epinephrine. In addition, Malamed noted that an additional 1.2 mL of the same anesthetic solution should be administered if only “partial anesthesia develops” (6). Malamed’s textbook does not define “partial anesthesia” either as a soft tissue or pulpal phenomenon. If Malamed is indicating a soft tissue phenomenon associated with subjective numbness or onset, it seems a definition of partial anesthesia would be needed in order to ascertain whether more anesthetic solution volume is required in a clinical situation. Sisk et al. noted a mean onset time of 7.68 minutes, again using a 1.8 mL volume of 2% lidocaine with 1:100,000 epinephrine with a second injection given if onset is not established by 10 minutes (85). Todorovic et al. found a range (1-20 minutes) with a mean onset time of 7 minutes using 2 mL 2% lidocaine with 1:100,000 epinephrine (79). Hung et al. waited for 15 minutes to achieve onset after administration
of the Gow-Gates block with 2.7 mL of 2% lidocaine with 1:100,000 epinephrine and noted a 100% rate of lip numbness among his 62 subjects (81). Results from pulp testing his patients at 0 min, 5 min, 10 min, 15 min, and 60 min after the injection, the first molar in the Gow-Gates group revealed 52 of 62 patients (83.9%) experiencing successful pulpal anesthesia, defined as no response to the maximum output (81) of the electric pulp tester. Gow-Gates himself describes the onset time from his eponymous injection as “rapid” and “extend[ing] buccally and lingually as far anteriorly as the region of the distal surface of the central incisor” (71). Gow-Gates noted that despite the attribution of anesthetic failure to an inadequate volume of anesthetic solution, he consistently used 2.2 mL of 2% lidocaine with 1:80,000 epinephrine (71). Gow-Gates stated that the technique was used in “excess of 50,000 cases” but does not note any scientific method associated with his observations. His article is an instructional treatise based on his observations of an admittedly large case series, but it is not a randomized controlled evaluation of anesthetic effects post-injection. Levy noted an onset time of at least 10 minutes. In his bilateral extraction model, Levy began extraction on the side of the mouth receiving an IANB, waiting until extraction was complete to initiate treatment on the Gow-Gates side. Therefore his onset time is perhaps not as reliable as others (74). Agren and Danielsson note a delay of over 10 minutes is possible pointing to subjects in their study in which onset was not established until 20, 30 and even 45 minutes post-injection of 1.8 mL of 2% lidocaine with 1:100,000 epinephrine (80). Though Agren and Danielsson’s study only included 12 patients, it is important to note that a slower onset is possible with this injection technique. Montagnese et al. administered 1.8 mL of 2% lidocaine with 1:100,000 epinephrine and waited for 10 minutes before asking patients if they felt
subjective lip numbness, at which point 98% of subjects confirmed subjective lip numbness (22). Finally, Goldberg et al. administered 3.6 mL of 2% lidocaine with 1:100,000 epinephrine and waited 21 minutes for subjective lip numbness at which time those subjects not experiencing lip numbness were eliminated from statistical analysis. Eight of forty subjects (20%) experienced failed lip numbness after receiving the Gow-Gates technique and 10 of 40 (25%) of the subjects receiving the Vazirani-Akinosi technique experienced no lip numbness. Evaluating only those subjects who did experience subjective lip numbness within 21 minutes, the authors noted a pulpal anesthesia onset time of 17 ± 12.8 minutes in the first molar, a statistically longer onset time than that obtained with the conventional IANB (23). Ultimately, this study’s wait time of 20 minutes before endodontic access certainly corresponds to the literature concerning the Gow-Gates injection and would provide ample time for a majority of patients to achieve subjective lip numbness. Our result of 92% lip numbness success also falls within an acceptable clinical window established by the conventional IANB.

In comparison, our evaluation of the Vazirani-Akinosi injection’s lip numbness success rate (63%) does not correspond to the block success rates of either the conventional IANB or the Gow-Gates injection. Our study allowed a wait-time of 20 minutes for the Vazirani-Akinosi, and an additional 5 minutes if no lip numbness was noted at 20 minutes. Our study design initially proposed a 20-minute wait-time for both injection techniques, however after a significant percentage of subjects failed to achieve lip numbness with the Vazirani-Akinosi technique, an additional 5 minutes were allotted to the Vazirani-Akinosi subjects’ post-injection wait-time. This additional period was added in order to capture subjects who may have had slower onset anesthesia. Though an
additional 5 minutes were granted to Vazirani-Akinosi subjects, only 3 subjects achieved lip numbness at 25 minutes when none was present at 20 minutes. Importantly, none of these 3 subjects achieved pulpal anesthetic success with the Vazirani-Akinosi injection suggesting that the additional 5-minute period is neither required nor recommended clinically. Overall, a longer onset is noted both in the Vazirani-Akinosi and Gow-Gates techniques, (23, 77, 79, 88).

Authors note various reasons for a longer onset when administering either of these injections. Writing about the Gow-Gates technique, Sisk suggests that a wait time of at least 10 minutes is indicated post-injection and before surgery is commenced due to the greater diameter of the mandibular nerve trunk in the area of injection and the distance of the nerves from the site of anesthetic deposition (77). Malamed also cites the increased diameter of the nerve trunk and distance (5-10 mm) from deposition site to the nerve as reasons for a slower onset in the Gow-Gates injection (6, 75). Todorovic also suggests that distance from deposition site to nerve trunks was the cause for slower onset in his evaluation of the Gow-Gates and Vazirani-Akinosi techniques (79). DeJong’s theory concerning the anatomical width of the nerve trunk may underline why onset can be slower in these injections. DeJong describes the peripheral bundles of the nerve trunk, the outermost layers supplying more proximal areas such as the cheek and posterior teeth, are first affected by the anesthetic solution but that fibers located near the core or center of the nerve that supply more distal areas such as the anterior teeth are not as quickly affected (101). It is possible that at the area of deposition for either the Gow-Gates or Vazirani-Akinosi techniques, where the V3 nerve has exited the foramen ovale, nerve fibers that innervate the lip are not as peripheral on the V3 nerve as they may be at the
lower or more conventional injection location, resulting in slower onset. However, even if this was the case, it does not explain why the success rate of the Vazirani-Akinosi injection was significantly lower than the Gow-Gates injection in our evaluation. Nor does this explain the comparable pulpal anesthetic success rate of the Gow-Gates technique to the conventional IANB technique. Simon et al. found via peripheral nerve stimulator that despite close proximity to the mandibular nerve before deposition, pulpal anesthetic success rates were similar to those found without use of the peripheral nerve stimulator (37). This refutes the suggestion that distance from the nerve trunk of 5-10 mm may play a role in anesthetic onset. If proximity to the nerve does not yield a statistically significant success rate over conventional IANB technique, it would appear that negligible distance from the nerve is insignificant in establishing anesthetic onset. However, if a sufficient amount of anesthetic solution is not deposited or diffused into the pterygomandibular space, the anatomical space housing the inferior alveolar nerve medial to the mandibular ramus before it enters the mandibular foramen into the inferior alveolar canal, the inferior alveolar nerve block may not be successful. Goldberg et al. proposed that failure of onset is a result of anesthetic solution deposition outside of the pterygomandibular space due to inaccurate needle placement (Gow-Gates) or lack of bony landmarks (Vazirani-Akinosi) (23). Differences in mandibular anatomy are implicit in a study such as this one in which a random sample of patients take part in treatment. Anatomical variation aside, it is unlikely that the senior operator’s technique was so incorrect after two months of calibration that improper technique could account for this study’s rate of block failure. Rather, it appears that if the success rate of the block with administration of the Vazirani-Akinosi injection is so unsuccessful as to yield a 63%
success rate for a trained operator, one may conclude that the technique is so variable (likely due to its lack of intraoral bony landmarks) that it is not recommended for routine restorative or endodontic procedures.

Of 38 subjects in the Vazirani-Akinosi group, 33 achieved subjective lip numbness by the 20-minute mark. Of the remaining 5 subjects, 3 achieved subjective lip numbness at 25 minutes when none was noted at 20 minutes. None of these 3 subjects experienced successful pulpal anesthesia resulting from the Vazirani-Akinosi block alone. The remaining 2 subjects had endodontic treatment initiated at 30 and 35 minutes post-injection due to scheduling delay in the clinic. These two patients had lip numbness at 30 and 35 minutes, respectively, because that was the first time they were assessed. It is certainly possible that these patients experienced lip numbness before the 30 or 35-minute mark. Other authors note a range of onset time from 40 seconds to 18 minutes for the Vazirani-Akinosi technique (6, 23, 79, 82-88). These ranges are described below in addition to volumes of anesthetic solutions utilized in each corresponding study. Akinosi noted an onset time for lip and tongue anesthesia at 40 seconds and 1 ½ minute onset for surgical anesthesia using 1.5-2.0 mL of 2% lidocaine with 1:80,000 epinephrine (82). Vazirani noted the use of a 2-inch, 25-gauge needle as appropriate for the desired insertion depth of 1.5 cm (83). Vazirani did not indicate how much anesthetic solution should be utilized when applying his technique nor did the author note an expected onset time for either soft tissue anesthesia or pulpal anesthesia. Vazirani did note that using his technique produced successful anesthesia 95% of the time. He did not define successful anesthesia or how this was measured within his article. Malamed advises a 40-90 second onset time for lip and tongue and a 5-minute onset sufficient for dental
procedures when using 1.8 mL 2% lidocaine with 1:100,000 epinephrine (6). It does not appear that these times are validated by any scientific research other than Akinosi’s observation of lip and tongue onset in 40 seconds as described above. Evaluating the Vazirani-Akinosi technique, Sisk found that at 10 minutes post-injection, 90% of subjects experienced anesthetic onset in the form of altered lip sensation (85). In Sisk’s study, 1.8 mL of 2% lidocaine with 1:100,000 epinephrine was used in a bilateral third molar extraction model (85). Examining the Vazirani-Akinosi technique, Donkor assessed lip numbness in his study at 5 minutes and 10 minutes post-injection, using 1.5 -2.0 mL of 2% lignocaine with 1:100,000 epinephrine (86). Donkor’s study also used an extraction model, but patients were not receiving a bilateral extraction, rather 200 patients requiring a lower posterior tooth (second premolar to third molar) were randomized via coin toss as to whether they received either the Akinosi or conventional IANB injection. Donkor explains that if no change in lip sensation occurred at ten minutes a supplementary injection was administered, however the failure rate of the Vazirani-Akinosi injection is omitted in his article. Yücel noted that at 5 minutes post-injection only 51% of his subjects experienced lip numbness, compared to 88% in the group that had received a conventional inferior alveolar block (87). Lip numbness was recorded for either technique, conventional IANB or Vazirani-Akinosi, if it occurred within 5 minutes; if at 10 minutes no lip numbness was observed, an undefined supplementary injection was given. A volume of 2.0 mL of lignocaine hydrochloride with 1:200,000 epinephrine was used in Yücel’s extraction model study in which 250 patients ages 19-64, requiring extractions of lower first of second molars participated (87). Employing the Vazirani-Akinosi technique, Gustainis and Peterson noted a 40-90 second lip and tongue onset and
a 4-minute onset that allowed for initiation of surgical procedures using a 1.5 -1.8 mL volume of 2% lidocaine with 1:100,000 epinephrine (84). Gustainis and Peterson concede that despite frequent use over a period of three years, no statistical data was collected for patients receiving this injection and that a success rate superior to the Gow-Gates or conventional IANB techniques cannot be claimed. It is important to note that despite the lack of scientific evidence in this study, the authors support the use of this injection in patients suffering from trismus. Todorovic et al. noted an onset time of 1-11 minutes with a mean of 3 minutes for lip numbness in his subjects after the Vazirani-Akinosi injection was administered utilizing 2.0 mL of 2% lidocaine with 1:80,000 epinephrine (79). Todorovic’s study included 90 subjects ranging in age from 19-62 years and is also a simple extraction model. Gonzalez et al. noted a mean onset of lip numbness at 3.8 minutes, longer than his comparison of the conventional IANB at a mean of 2.9 minutes (88). Gonzalez et al. utilized a 1.8 mL volume of 4% articaine (in both Vazirani-Akinosi and IANB injections) and a 25 mm depth of insertion for the Vazirani-Akinosi injection (88). In his third molar extraction model, Gonzalez et al. defined failure as the existence of pain during the extraction or the inability to elicit an anesthetic effect: 3 of 28 patients (10.7%) in the IANB group were considered failures whereas 5 of 28 subjects (17.8%) failed in the Akinosi group. In each of the evidence-based studies described above, an extraction model was employed. In an extraction model, teeth may be either asymptomatic or symptomatic. No delineation is made in these studies regarding diagnosis of the pulp, e.g. normal, asymptomatic irreversible pulpitis, symptomatic irreversible pulpitis, or necrosis. The lack of diagnostic information makes it difficult to compare success rates of these studies to subjects in our study who were all
diagnosed with symptomatic irreversible pulpitis. As discussed previously in the literature review, patients experiencing symptomatic irreversible pulpitis have different anesthetic concerns than patients with healthy, or asymptomatic, teeth.

Goldberg et al. evaluated the Vazirani-Akinosi injection using 3.6 mL of 2% lidocaine with 1:100,000 epinephrine (23). The authors noted an insertion depth of 30 mm. The average time of onset for pulpal anesthesia was noted at 18 ± 12.1 minutes (23). The current study’s wait time of 20 minutes, with an additional 5 minute period, before endodontic access was initiated, corresponds to the literature concerning the Vazirani-Akinosi injection and would provide ample time for a majority of patients to achieve subjective lip numbness. However, our result of 63% lip numbness success does not fall within an acceptable clinical window established by the IANB. This notably low success rate for block success is attributable to the inherent variability of the Vazirani-Akinosi technique described by many authors as described above. Because this technique does not employ any bony landmarks and does not account for variable flaring of the mandibular ramus, the ability to achieve consistent block success is questionable, as evidenced by this study. Previous studies such as Goldberg’s (23) also note the number of block failures encountered with the Gow-Gates and Vazirani-Akinosi technique but by and large, most studies focusing on these injection techniques do not provide a rate of block failure. For this reason, our evaluation found it important to assess the substantially lower success rate of the Vazirani-Akinosi injection.

Our study varies from Goldberg’s evaluation (23) in large part because the forty subjects evaluated in that study had healthy, asymptomatic, vital pulps with no areas of pathosis or infection. The 120 subjects evaluated in this investigation were all diagnosed
with symptomatic irreversible pulpitis. Additionally, pulp testing with an EPT was performed in Goldberg’s study (23) whereas endodontic access and instrumentation was performed in this investigation.

During our investigation, we found it appropriate to compare the success rates of the two injection techniques against the established historical controls of the conventional IANB injection in symptomatic irreversible pulpitis patients. This study did not include its own, third group consisting of conventional IANB technique subjects. Including this third group would require increased recruitment of qualified patients. However, sufficient studies examining the effects of the IANB in symptomatic irreversible pulpitis (onset times, volume, epinephrine concentration, placement, pre-medication, pulpal anesthetic success) exist such that a comparison between the IANB and the two tested techniques utilizing historical data is possible.

Tables 4 and 5 present the pulpal anesthetic success of the Gow-Gates and Vazirani-Akinosi injections. The Gow-Gates yielded a 35% pulpal anesthesia success rate while the Vazirani-Akinosi produced a 16% success rate. In this study, success was defined as the ability to access and instrument the tooth without pain (a VAS score of zero) or mild pain (A VAS score less than or equal to 54 mm). Following the initial block injection, 39 patients in the Gow-Gates group and 32 patients in the Vazirani-Akinosi group required a buccal infiltration of one cartridge of 4% articaine with 1:100,000 epinephrine. This supplemental technique provided successful pulpal anesthesia in 20 of the 39 subjects in the Gow-Gates group (49%) and 12 of the 32 subjects in the Vazirani-Akinosi group (38%). Nineteen patients in the Gow-Gates group and 20 patients in the Vazirani-Akinosi group did not achieve successful pulpal
anesthesia following the buccal infiltration and were given an additional cartridge of 2% lidocaine with 1:100,000 epinephrine intraosseously. This supplemental injection provided successful anesthesia for 14 of the 19 subjects (74%) in the Gow-Gates group and 11 of 19 (58%) subjects in the Vazirani-Akinosi group. A second intraosseous injection was administered for subjects that did not achieve successful pulpal anesthesia up to this point, 4 in the Gow-Gates group and 7 in the Vazirani-Akinosi group. The second intraosseous injection provided successful anesthesia to 3 of 4 subjects (75%) in the Gow-Gates group and 2 of 7 subjects (29%) in the Vazirani-Akinosi group. Two patients received IL injections: one of which provided successful pulpal anesthesia in the Vazirani-Akinosi group and the other did not provide successful pulpal anesthesia but allowed for administration of an intrapulpal injection which did provide successful pulpal anesthesia for the subject. Seven subjects received intrapulpal injections. There was no instance in which an intrapulpal injection did not achieve successful pulpal anesthesia. There was no instance in which a subject could not finish the emergency procedure.

There was a statistically significant difference (p = 0.0381) in the block success of the Gow-Gates versus the Vazirani-Akinosi block injections. The statistical power associated with this conclusion is lessened due to the smaller sample size of the Vazirani-Akinosi Group; 38 total subjects versus 60 total subjects in the Gow-Gates group. The sample size in the Vazirani-Akinosi group was secondary to the occurrence of decreased block success (lip numbness) while employing this technique.

It is useful to compare the Gow-Gates and Vazirani-Akinosi success rates against the historical controls of the conventional IANB studies to evaluate whether or not either of these two tested techniques provide clinically superior anesthesia. The following
studies utilized the same method of diagnosis and definition of success as our study: patients presented with moderate-to-severe pain as confirmed via a 170 mm VAS resulting from a vital posterior mandibular tooth and success was defined as patient sensation of no or mild pain during access and instrumentation, also verified by a 170 mm VAS. Therefore it is useful and suitable to compare the IANB success rates in symptomatic irreversible pulpitis patients in these studies to the success rates established by our investigation.

Nusstein et al., in their treatment of posterior teeth diagnosed with symptomatic irreversible pulpitis, showed the supplemental intraosseous injection of 2% lidocaine with 1:100,000 epinephrine was successful when conventional techniques (maxillary infiltration and mandibular nerve blocks) failed. Administration of the intraosseous injection increased success rates from 19% to 90%. The inferior alveolar block alone in these patients was successful, defined as pain-free endodontic access and instrumentation just 19% of the time. This is lower than the 35% success rate with the Gow-Gates in this study, but higher than the 16% success rate in the Vazirani-Akinosi group (60).

In Reisman et al.’s evaluation of 3% mepivacaine as an intraosseous injection in patients diagnosed with symptomatic irreversible pulpitis, the authors found the inferior alveolar nerve block to be 25% successful with the first intraosseous injection increasing the success rate to 80% and the second intraosseous injection increasing the success rate to 98% (62). The 25% success rate of the inferior alveolar block alone in the same patient population evaluated in our study is again lower than our 35% success rate for the Gow-Gates technique, but higher than the 16% success rate found among Vazirani-Akinosi subjects.
The significance of needle deflection in success of the inferior alveolar nerve block in patients with symptomatic irreversible pulpitis, was studied by Kennedy et al. (65). Sixty-four adult patients were included and randomly received 2.8 mL of 2% lidocaine with 1:100,000 epinephrine with either a conventional IAN block or a bidirectional-rotation-technique, using the Wand II computer-assisted anesthesia system. The anesthetic success rate for the conventional IAN block was found to be 50% whereas the bidirectional IAN technique yielded a 56% success rate. The study revealed no significant differences between the success rates of these two techniques, indicating that the orientation of the needle bevel and subsequent potential for deflection, does not affect pulpal anesthesia (65). The success rate of 50% and 56% are both higher in comparison to our study’s success rates of 35% using the Gow-Gates technique and 16% using the Vazirani-Akinosi technique.

In separate studies, Tortamano et al. (54) and Claffey et al. (55) compared the anesthetic efficacy of 2% lidocaine with 1:100,000 epinephrine versus 4% articaine 1:100,000 epinephrine for an inferior alveolar nerve block in patients experiencing symptomatic irreversible pulpitis in mandibular posterior teeth. Both studies revealed no significant difference between the two solutions, noting neither anesthetic solution effectively managed pain during treatment (54, 55). Tortamano’s success rate of the IAN block using 3.6 mL 2% lidocaine with 1:100,000 epinephrine in patients with symptomatic irreversible pulpitis, was 45%. It must be noted that Tortamano’s group utilized a different pain scale than a 170 mm VAS to assess success. Instead, the study employed a 0 – 3 pain scale in which scores of 0 (no pain) or 1 (mild pain) were considered successful IAN blocks, and scores of 2 (moderate, bearable pain) or 3 (severe,
intense, and unbearable pain) were considered unsuccessful IAN blocks. The different pain scale employed in Tortamano’s study may account for their higher (45%) rate of success in patients with symptomatic irreversible pulpitis. Claffey et al. found a 23% success rate using 2.2 mL of 2% lidocaine with 1:100,000 epinephrine (55). Again, our Gow-Gates technique success rate of 35% falls within a range established by the 45% Tortamano and 23% Claffey success rates, but the Vazirani-Akinosi success rate of 16% falls outside of this range.

Matthews et al. evaluated the effect of 1.8 mL infiltration of 4% articaine with 100:000 epinephrine in patients with symptomatic irreversible pulpitis when the inferior alveolar nerve block fails (57). Fifty-five of 82 total subjects (67%) experienced unsuccessful pulpal anesthesia thus requiring a supplemental buccal infiltration of 4% articaine with 1:100,000 indicating that the inferior alveolar block success rate obtained by Matthews et al. for symptomatic irreversible patients was 33%. This rate is within range of the 35% success rate obtained in this study with the Gow-Gates technique and noticeably higher than the 16% success rate obtained with the Vazirani-Akinosi technique.

Oleson et al. (45) evaluated the preoperative effect of 800 mg ibuprofen on the success of the inferior alveolar nerve block in 100 patients diagnosed with symptomatic irreversible pulpitis and in moderate to severe pain. No significant difference was noted between the ibuprofen group and the placebo group, success rates of the inferior alveolar block were 41% and 35%, respectively. The success rate for the Gow-Gates technique matches Oleson’s placebo group at 35% while the Vazirani-Akinosi group displays a lower success rate of 16%.
Simpson et al. (44) studied the preoperative effect of a combination of ibuprofen and acetaminophen on the inferior alveolar nerve block in 100 patients diagnosed with symptomatic irreversible pulpitis. A success rate of 32% was found among the ibuprofen/acetaminophen group and 24% for the placebo group. Our investigation noted a 35% success rate with the Gow-Gates technique, certainly within range of Simpson et al.’s ibuprofen/acetaminophen group, however the Vazirani-Akinosi technique was lower than either the 32% experimental or the 24% placebo group’s success rates in Simpson et al.’s study.

Aggarwal et al. further studied the supplemental buccal and lingual infiltrations of 4% articaine with 1:200,000 epinephrine versus 2% lidocaine with 1:200,000 epinephrine after an inferior alveolar nerve block in patients with irreversible pulpitis and revealed increased success rates with a statistical difference in articaine success versus lidocaine success (59). However, neither supplemental technique provided acceptable success rates; the supplemental articaine infiltration produced a 67% success rate and the supplemental lidocaine infiltration produced a 47% success rate (59). In their control group of symptomatic irreversible pulpitis patients receiving simply an inferior alveolar nerve block with 1.8 mL 2 % lidocaine with 1:200,000 epinephrine, Aggarwal et al. noted a 33% success rate of successful anesthesia, defined by the authors as none or mild pain as recorded by the patient on a VAS. Once again, our study’s 35% success rate with the Gow-Gates injection is comparable to the 33% success rate established in Aggarwal’s study, but the Vazirani-Akinosi’s 16% success rate is comparatively low.

In Stanley et al.’s study of pre-operative administration of nitrous oxide to patients diagnosed with symptomatic irreversible pulpitis, the placebo group experienced
a 28% success rate of pulpal anesthesia with the conventional inferior alveolar block (66). In Fullmer et al.’s evaluation of pre-operative hydrocodone administration to the same patient population, the authors’ placebo group also experienced a 28% pulpal anesthetic success rate (48). This study’s 35% pulpal anesthetic success rate from the Gow-Gates group compares well with both of these previous studies, but again this study’s Vazirani-Akinosi success rate of 16% compares poorly.

The pulpal anesthetic success rate of the Gow-Gates injection as found in this study (35%) is commensurate with the success rates found by other authors evaluating similar patient populations (patients diagnosed with symptomatic irreversible pulpitis) when using the conventional inferior alveolar nerve block. Notably, earlier studies such as Matthews et al. (57) who reported a 58% success rate are much higher than the success reported by this investigation. In Matthews study, the success rate described patients receiving a buccal infiltration of one cartridge of 4% articaine with 1:100,000 epinephrine after a failed conventional IANB, rather than describing failure of the initial, conventional IANB (57). Additionally, earlier studies such as Ianiro et al. (46) and Kennedy et al. (65) had smaller sample sizes, which affect the statistical power and therefore validity of their results. As seen above in our comparison of more recent literature, this study would suggest that the Gow-Gates injection does not provide any additional anesthetic success or improvement over the conventional inferior alveolar nerve block. Neither does this technique perform any worse or with less success than the conventional inferior alveolar nerve block. This was an expected finding because despite a different deposition site, the status of pulpal tissue diagnosed with symptomatic irreversible pulpitis is no more susceptible to a mandibular nerve block initiated at the
site of the mandibular foramen (conventional IANB) than it is to a mandibular nerve block initiated at the site of the mandibular condylar area. In comparing the conventional IANB to the Gow-Gates technique, post-operative effects of the injection may incline the clinician towards the use of one over the other technique. This study did not evaluate patients’ post-operative impressions and symptoms. It is possible that if the Gow-Gates has negative post-operative effects, then the conventional IANB would be recommended given the two techniques’ commensurate anesthetic success rates. Since no acute post-operative complications presented (to our knowledge) and the anesthetic success rates resulting from these two techniques appear to be compatible, we do not recommend the use of the Gow-Gates over that of the conventional inferior alveolar nerve block or vice versa. Ultimately, this investigation suggests that either of these techniques will achieve similar anesthetic results in routine endodontic treatment.

The Vazirani-Akinosi injection evaluated by this study demonstrated a success rate of 16%. However, this rate was not as statistically robust as desired, due to the low sample size of patients in this group. Our sample size in the Vazirani-Akinosi group was lower than the Gow-Gates sample size because of the Vazirani-Akinosi injection’s high rate of block failure. Notably, the clinical usefulness of the Vazirani-Akinosi injection in patients with symptomatic irreversible pulpitis is suspect given its low rate of block success (63%) and lack of lip numbness (Table 4). The technique would be clinically useful if a successful block (lip numbness), despite its relatively low presentation, guaranteed a high pulpal anesthetic success rate. This study did not show significantly increased levels of pulpal anesthesia in successful Vazirani-Akinosi blocked subjects, therefore the Vazirani-Akinosi’s use in patients with symptomatic irreversible pulpitis is
not recommended unless other indications exist that necessitate the use of this technique, such as trismus.

Post-operative complications encountered by these techniques are reportedly few. This study did not specifically note post-operative effects or symptoms, however patients returning for completion of endodontic treatment or for follow-up appointments were asked by the operator how they felt after treatment and if they experienced any noticeable soreness or stiffness in the area of the injection. The operator noted no instances of positive aspiration while administering either injection technique. No patients in the Gow-Gates group recalled any adverse symptoms but one female patient in the Vazirani-Akinosi group was noted to have trismus and limited mouth opening four weeks after her study appointment. Several patients (four) in the Vazirani-Akinosi group noted numbness in their upper lip during onset of successful subjective lower lip anesthesia. Gow-Gates (71) does not mention trismus nor any other complications associated with his eponymous injection while Levy (74) affirms the same, noting no post-operative complications in his use of either the Gow-Gates or conventional IANB. Malamed noted that there are fewer muscle attachments in the area of the Gow-Gates injection, as compared to the conventional IANB injection site, so the Gow-Gates injection enjoys a lower incidence of trismus post-injection. Malamed added that though there are many causes for trismus and limited mouth opening, muscle trauma is the most common etiology meaning that with fewer muscle attachments in the area, the Gow-Gates technique produces much fewer incidences of post-injection trismus than the conventional inferior alveolar nerve block technique (75). Akinosi noted that in his use of the injection over a four-year time period, no significant complication had yet been
recorded (82). Gustainis and Peterson concur with this finding, noting that no episodes of post-infection trismus had occurred with their use of a 25-G needle in the Vazirani-Akinosi technique (84). Donkor noted that the Vazirani-Akinosi technique produced a wider variety of unexpected symptoms including “tingling in the upper lip” (86). Furthermore, one of Donkor et al.’s subjects who experienced this altered sensation in the upper lip also experienced a blanching of skin in the infra-orbital area (86). In his study, Gonzalez noted that one subject receiving the Vazirani-Akinosi technique claimed to be unable to close an eye though the problem rapidly subsided (88). Gonzalez also notes the post-operative complication triad of pain, inflammation, and trismus associated with extraction of the third molar could make it difficult to discern whether the etiology of trismus is the extraction or the injection technique in a third molar extraction model study.

It is important to compare our findings with others who have examined the Gow-Gates and Vazirani-Akinosi techniques in patients with symptomatic irreversible pulpitis. In patients with irreversible pulpitis, Sherman et al. (89) compared 4% articaine with 1:100,000 epinephrine and 2% lidocaine with 1:100,000 epinephrine using the Gow-Gates technique in posterior teeth. Subjects rated their initial pain on a VAS and were then given either 1.7 mL of 4% articaine with 1:100,000 epinephrine or 1.8 mL of 2% lidocaine with 1:100,000 epinephrine for a Gow-Gates or maxillary infiltration as appropriate for their symptomatic tooth. The two anesthetic solutions were randomly assigned to the subjects and masked with an opaque label so as to blind the operator. The subject’s contralateral canine was utilized as the nonanesthetized control to ensure the subject’s reliability. Ten minutes postinjection, the experimental tooth was tested with
Endo-Ice® every minute for 5 minutes. The authors defined pulpal anesthesia as a negative pulpal response to the Endo-Ice after 15 minutes. If a negative response was not attained within 15 minutes, the injection was considered missed and the subject eliminated from the study. Once pulpal anesthesia was verified, a rubber dam was placed on the experimental tooth and endodontic access was initiated. Patients rated their discomfort on a VAS after access was completed. The block was considered successful if the subject’s tooth was accessed with a pain rating no greater than mild pain (greater than 0 mm but less than 54 mm).

Sherman found that the block anesthetic success was achieved in 87.5% of all patients who qualified for treatment, four anesthetic failures were observed in the mandibular arch and one in the maxillary arch however the authors note no correlation observed between anesthetic type and failure or tooth arch and failure (89). While the authors found no difference between the two anesthetic formulations (articaine versus lidocaine), the study only used 10 subjects per group. The number of patients in each group would have to be higher to reach clinical conclusions. One patient in the lidocaine group and one patient in the articaine group did not experience pulpal anesthesia at the 15 minute mark postinjection and were excluded from the study, however the authors do not note which injection technique (a Gow-Gates or maxillary infiltration) these excluded subjects received. The authors note a 90% success rate in 10 patients receiving the Gow-Gates technique with 4% articaine with 1:100,000 epinephrine and a 72.7% success rate in those eleven receiving the same injection but with 2% lidocaine with 1:100,000 epinephrine. Again, the numbers of subjects in each group would have to be higher in order to reach clinical conclusions. Certainly, our study’s success rate of 35% in sixty
subjects receiving the Gow-Gates technique with 2% lidocaine with 1:100,000 epinephrine is not comparable to the 72.7% success rate found by Sherman et al. This difference in success rate is expected given the marked increase in sample size in our investigation and differences in study design. Sherman et al. cold tested the target tooth every minute for 5 minutes, 10 minutes after the injection. If cold was felt at the 15-minute mark, the injection was considered missed and the patient eliminated from the study. This elimination of subjects effectively amplified the success rate of the injections (Gow-Gates or maxillary infiltration) since only patients unresponsive to cold 15 minutes post-injection continued within the limits of the study and were evaluated. No cold testing was done in this study thereby allowing a more accurate representation of the pulpal anesthetic success achieved with the Gow-Gates injection.

Aggarwal et al. found that the Gow-Gates technique improved success over the conventional inferior alveolar nerve block in patients with irreversible pulpitis. The success rates were 52% and 36%, respectively (90). The Vazirani-Akinosi technique had a success rate of 41% (90). The numbers in each group of patients were small with twenty-four receiving Vazirani-Akinosi blocks, twenty-five receiving Gow-Gates blocks, twenty-two receiving the control – a conventional inferior alveolar block, and twenty-six receiving a buccal-plus-lingual infiltration. These small group numbers may have affected the results. Our investigation of sixty subjects receiving the Gow-Gates injection yielded a 35% success rate, certainly lower than the 52% established by Aggarwal et al. This is expected given our increased sample size. The Vazirani-Akinosi technique was utilized on 38 subjects in our study, an admittedly smaller sample size than 60 subjects, but larger than Aggarwal’s 24 subjects. In our study, a 16% pulpal
anesthetic success rate was noted, lower than the 41% success rate found by Aggarwal et al. The difference between these success rates could be explained by our increased sample size or variations in reported pain levels among subjects participating in Aggarwal’s study versus the subjects who consented to treatment in our study. In Aggarwal’s investigation, subjects were “actively experiencing pain” and asked to complete a 170 mm VAS, however the authors do not delineate whether or not subjects were excluded or included based on their reported level of pain. It may be inferred that some of the subjects participating in the study were not in moderate to severe pain or experiencing symptomatic irreversible pulpitis (an inclusion criteria utilized in this investigation) thereby skewing the success rates. Recall from the literature review that pulpal anesthetic success rates are lower in patients diagnosed with symptomatic irreversible pulpitis for various reasons including: the inability of conventional anesthetic techniques to consistently provide adequate pulpal anesthesia, nerves originating in inflamed tissues may have higher resting potential and therefore decreased excitability thresholds that prevent local anesthetic from sufficiently blocking impulse transmission in these areas, increased expression of tetrodotoxin-resistant sodium channels in irreversible pulpitis nerve tissue results in increased resistance to the action of local anesthetics, a general increase in expression of sodium channels, and that patients experiencing pain are often apprehensive resulting in lower thresholds for pain. The Vazirani-Akinosi’s pulpal success rate found by this investigation is not statistically relevant due to the high rate of block failure encountered in using this injection technique. For this reason, the sample size studied in this study’s review of the Vazirani-Akinosi technique was reduced from 60 to 38 subjects. It must be noted that with a high
rate of block failure, this investigation suggests that the Vazirani-Akinosi technique is not recommended for routine clinical application in patients diagnosed with symptomatic irreversible pulpitis.

Success rates for the buccal infiltration injection and the intraosseous injections are also shown in Table 5. A 51% success rate (20 of 39 subjects) was achieved by the buccal infiltration in the Gow-Gates group and a 38% success rate (12 of 32 subjects) by the Vazirani-Akinosi group among those subjects experiencing subjective lip numbness, but failed pulpal anesthesia, resulting from the initial block. No statistically significant difference was found between the Gow-Gates and Vazirani-Akinosi subjects requiring a buccal infiltration ($p = 0.2455$). The success rates of the buccal infiltration fall within a range established by previous symptomatic irreversible studies such as Matthews et al. (57) who established a 58% success rate, Oleson et al. (45) who experienced a 52% success rate in their placebo group, Simpson et al. (44) who established a 24% success rate in their placebo group, Stanley et al. (66) who noted a 61% success rate in their placebo group and Fullmer et al. (48) who found a 42% success rate in their placebo group.

Intraosseous success rates are divided into two groups: those subjects receiving one intraosseous injection (IO #1) and those subjects requiring two intraosseous injections (IO #2) because the first did not provide adequate pulpal anesthesia for routine endodontic treatment. In the IO #1 group, subjects who had initially received the Gow-Gates technique experienced a 74% success rate (14 of 19 subjects) with the first intraosseous injection and subjects who had initially received the Vazirani-Akinosi injection experienced a 58% success rate (11 of 19 subjects). No statistically significant
difference was noted between the Gow-Gates and Vazirani-Akinosi groups (p = 0.4351). In the IO #2 group, 75% of Gow-Gates subjects (3 of 4) achieved pulpal anesthetic success with the second intraosseous injection whereas 29% of the Vazirani-Akinosi subjects (2 of 7) achieved pulpal anesthetic success with this injection. Again, no statistically significant difference between the groups was noted (p = 0.2424). Because the numbers in the intraosseous groups (both IO #1 and particularly IO #2) were so small, a comparison of the success rates at this level is statistically untenable. However, it is useful to compare this investigation’s success rates to previous studies. Oleson et al. (45) noted a 94% success rate of the intraosseous injection in their placebo group and Simpson et al. (44) noted a 79% success rate for the intraosseous injection their placebo group. Stanley et al. (66) noted a 93% success rate and Fullmer et al. (48) noted a 76% success rate for the intraosseous injection in their respective placebo groups. Nusstein et al. (60) noted a 90% success rate among mandibular teeth diagnosed with symptomatic irreversible pulpitis, however this success rate included teeth that responded positively to EPT and cold testing and were therefore administered an intraosseous injection before treatment was initiated. The intraosseous success rate for the Gow-Gates subjects in this study (74% and 75%) falls within the range established by previous studies, whereas the intraosseous success rate (58%, 29%) for the Vazirani-Akinosi subjects does not. Again, the numbers included in the intraosseous groups are simply too small to make valid statistical assumptions about the success of the intraosseous injections.

Table 6 presents pulpal anesthetic success of the block injections, Gow-Gates or Vazirani-Akinosi, by gender. A statistically significant difference is noted among female patients participating in the study (p = 0.0136). This finding may be due to the differing
sample sizes among the two groups. Results yielded a 40% pulpal anesthesia success rate among females in the Gow-Gates group while the Vazirani-Akinosi injection produced a 10% success rate in females evaluated in that group. The Gow-Gates group consisted of 60 subjects, 43 of which were female, whereas the Vazirani-Akinosi group consisted of 38 subjects, 21 of which were female. Comparing 43 females in the Gow-Gates group to 21 females in the Vazirani-Akinosi group is simply not an effective way in which to compare pulpal anesthetic success of these injections. Seventeen male subjects were treated with the Gow-Gates technique and another seventeen male subjects with the Vazirani-Akinosi technique. To add to this aforementioned (Table 3) coincidence, it is was even more curious to find that among the two technique groups, the equivalent number of male subjects, thirteen, reported failed pulpal anesthesia during treatment resulting in a 24% success rate for male subjects receiving either injection (p = 1.0000). This was an entirely random event due to the fact that subjects included in the study were randomly assigned a particular injection technique once they met the inclusion criteria and gave informed consent. As seen above, differences in success rates may be attributed to lower initial group sizes made even smaller by gender division. Though gender differences are visible – and there may indeed be a valid argument for this admittedly dynamic issue of gender-specific response – success rates are so low that the addition of supplemental anesthesia is evident. Though we have discussed low success rates among low sample sizes, it is important to remember that despite the numbers, none of the success rates established by this investigation are clinically adequate. The parsing of low sample sizes and low success rates is secondary to the imperfect clinical application of these injection techniques.
Tables 7-9 reveal the pain associated with insertion, placement, and deposition scores of the Gow-Gates and Vazirani-Akinosi injection techniques as described by patients on a 170 mm VAS. It has been shown that patients presenting with symptomatic irreversible pulpitis experience moderate to severe pain 57-89% of the time with the three phases (insertion, placement, deposition) of the conventional IANB (67). In a retrospective analysis, McCartney et al. (67) noted that needle insertion resulted in 59% of women and 55% of men recording their pain as moderate and 9% of women and 2% of men rating insertion pain as severe. Needle placement was found to be significantly more painful than the insertion phase for men, and significantly more painful than insertion or deposition for women. For men, placement resulted in 58% of subjects recording moderate pain and 13% recording severe pain; for women moderate pain during this phase was recorded for 70% of the subjects and severe pain for 10% of the subjects. For the anesthetic solution deposition phase, both 52% of the men and women recorded pain as moderate and 21% of women and 14% of men rated deposition pain as severe. The authors note that a higher incidence of pain among these three stages compared to pain experienced in these stages among asymptomatic patients is likely due to the fact that the subjects in this study were in pain and possibly more anxious.

Anecdotally, several authors suggest that the Vazirani-Akinosi technique results in a less painful injection because the needle does not have to pass through the anatomical structures that lie within the insertion path of the conventional IANB or Gow-Gates injection (82, 83). Vazirani noted that as the needle is inserted, there is no marked muscle resistance resulting in a “glide” of the needle into the pterygomandibular space. Vazirani also noted that insertion creates little or no pain because of the absence of
terminal nerve endings in adipose tissue (83). Akinosi noted that because the tissues are lax when the mouth is in a relaxed closed or semi-open state, penetration of the needle is “relatively painless” (82). Akinosi also notes that the advantage of loose areolar tissue deep in the pterygomandibular space into which anesthetic solution can be deposited and accommodated without pain (82). Todorovic notes no statistically significant difference among the three injection techniques concluding all three were “mostly painless” (79).

Goldberg et al.’s (23) study of the conventional IANB, the Gow-Gates, and the Vazirani-Akinosi technique yielded no statistically significant difference among them (p > 0.05) in terms of insertion and deposition pain as measured by a 170 mm VAS. Placement of the needle was not recorded. Goldberg found insertion pain for the Gow-Gates injection to elicit mild pain for 63% of his subjects (25 of 40) and moderate pain for 25% (10 of 40) (23). For the Vazirani-Akinosi, mild pain was recorded at 55% of subjects (22 of 40) and moderate pain at 25% of subjects (10 of 40). Regarding deposition pain, no pain was recorded 32% of the time (13 of 40) for the Gow-Gates technique and 35% (14 of 40) for the Vazirani-Akinosi technique. Mild pain was recorded 55% (22 of 40) and 52% (21 of 40) for the Gow-Gates and Vazirani-Akinosi techniques, respectively, and moderate pain at 12% (5 of 40) for both techniques (23).

Concerning specifically the Gow-Gates technique, Hung et al. (81) noted a significant difference in insertion pain between the conventional IANB (63%) and the Gow-Gates injection (45.2%). However, this study did not employ a VAS but rather a three-level rubric consisting of: none, mild/endurable, and severe (81). Furthermore, the authors do not explain how or when patients evaluated needle insertion for either the conventional or the Gow-Gates technique. In his bilateral extraction model study, Levy
noted that he observed patients remarking that the conventional IANB technique just hurt more than the Gow-Gates injection, though patients seemed to identify the needle’s sounding of the condylar neck with the incidence of pain (74). In terms of preference of one technique over the other, Levy notes that 14 of 26 patients preferred the conventional IANB, 9 preferred the Gow-Gates technique, 5 patients noted little difference, and 3 had no preference. No statistically significant difference was noted among these responses (74). In Montagnese et al.’s comparison of the conventional IANB and the Gow-Gates injection, the authors asked patients whether or not the injection was painful by asking, “Did the injection hurt?” to which 40% (16 of 40) replied that the conventional IANB was painful and 50% (20 of 40) answered that the Gow-Gates was painful. No statistically significant difference was noted between these two groups (22). Again, Goldberg’s (23) evaluation of the three block techniques is most useful for our comparison because that study required patients to note on a 170 mm VAS their pain perception of insertion, placement and deposition for each injection technique. Goldberg et al.’s (23) study appears to be the most objective methodology concerning injection pain encountered in the literature about the Gow-Gates and Vazirani-Akinosi techniques, and is also the most comparable to methods employed in our investigation.

In our study, no statistically significant difference was found between the two techniques in the insertion, placement, or deposition phases (Table 7). Of the three injection phases (insertion, placement, and deposition) the highest mean recordings are found to be solution deposition for both the Gow-Gates and the Vazirani-Akinosi at 66.8 ± 36.5 mm and 65.0 ± 38.2 mm, respectively. This is different than values found by McCartney et al. in their evaluation of the conventional inferior alveolar technique in
which placement was found to be the most painful stage of the injection (67). The placement phase in the Gow-Gates and the Vazirani-Akinosi techniques may be less painful than the conventional inferior alveolar technique in symptomatic irreversible pulpitis patients because of the location of these injections. In the Gow-Gates the insertion of the needle is higher than the conventional IANB resulting in different structures through which the needle passes. In the conventional IANB, the needle may pass through the medial pterygoid muscle, a potentially painful event. The needle may also pass through the medial pterygoid muscle in the Gow-Gates technique but this is less likely as the condylar area is superior to the inferior-distal track of the muscle as it travels from its origin point (the medial aspect of the lateral pterygoid plate of the sphenoid bone) to the site of insertion (the lower and dorsal part of the medial surface of the mandibular ramus). Even if the insertion track of the Gow-Gates needle did pass through a portion of the musculature, it would more likely be the attachment site of the lateral pterygoid muscle, which inserts at the neck of the condyle after originating at the lateral aspect of the pterygoid plate of the sphenoid bone. The lateral pterygoid muscle may be more tendinous in this area, rather than the thicker, more fibrous portion of the medial pterygoid muscle that lies deep to the pterygomandibular raphe through which the conventional IANB needle may pass. The Vazirani-Akinosi technique bypasses the puncture of musculature by the needle, which may explain why this injection is less painful than the conventional IANB. It must be noted that neither the Gow-Gates nor the Vazirani-Akinosi techniques are remarkably less painful than the conventional IANB. Comparing this study against McCartney et al.’s (67) review is only one comparison of these two techniques and neither may actually be less painful injections; as discussed
previously, most studies show that there is no significant difference between these two
techniques (Gow-Gates and Vazirani-Akinosi) and the conventional IANB (22, 23, 74,
79). If one or both of the techniques were significantly less painful, it may then be
clinically advantageous to employ either of these techniques in symptomatic irreversible
pulpitis patients. In discussing placement pain it is important to remember that placement
pain was second to solution deposition pain, but that the pain levels experienced during
placement and deposition are really quite close. For the placement phase, the Gow-Gates
group, 42% of patients note mild pain during insertion and 53% note moderate pain
whereas deposition values are 33% for mild pain and 57% for moderate pain. In the
Vazirani-Akinosi group, placement values were 37% mild pain and 39% moderate while
deposition values were 37% mild pain and 53% moderate pain (Table 9). Effectively,
there is not enough significant information regarding pain values experienced as a direct
consequence of the specific injection techniques to warrant the clinical use of one over
the other. In this study, the Vazirani-Akinosi technique has demonstrated a clinically
unacceptable rate of block failure for routine clinical use and the Gow-Gates technique
has comparable pulpal anesthetic success rates to the conventional IANB technique.
Consequently, our investigation does not recommend the use of the Vazirani-Akinosi
technique for routine clinical use, and suggests there is no strong evidence in favor of
either the Gow-Gates or the conventional IANB techniques for routine clinical use.

Examination of pain experienced during these three phases as separated by gender
(Table 8) reveals that no statistically significant differences in pain of the Gow-Gates and
Vazirani-Akinosi injections were noted among males or females participating in the
study. Table 9 illustrates the pain of the Gow-Gates and Vazirani-Akinosi injections by
stage. In the Gow-Gates group, the majority of subjects found the injection to be mild or moderate in nature with 58% ranking insertion as mild and 36% ranking it as moderate, 42% ranking placement as mild and 53% ranking it as moderate, and 33% ranking deposition as mild and 57% of subjects ranking this stage as moderate. In the Vazirani-Akinosi group insertion was noted by 55% of subjects as mild and 29% of subjects as moderate, placement was ranked by 37% of subjects as mild and 39% of subjects as moderate, and the deposition stage was ranked by 37% of subjects as mild and 53% as moderate. Notably, most subjects (76%-95%) reported the three stages of the injection to be mild or moderate in nature for both techniques. These values compare favorably with values found by McCartney et al. (67) who found insertion rates to be reported as 35% mild and 57% moderate (92% combined), placement among men and women to range from 14% - 30% as mild and 48%-60% as moderate (62% - 90% combined), and deposition rates reported as 26% mild and 52% moderate (78% combined). In Oleson et al.’s study, 98% of the placebo group reported insertion pain as none, mild or moderate, 96% reported placement pain as either mild or moderate, and 90% reported deposition pain as mild or moderate (45). Simpson et al.’s study reported lower findings; insertion, placement, and deposition pain values were reported as falling within mild or moderate categories, as defined by the 170 mm VAS, 40%, 42%, 42% of the time, respective to the three injection phases (44). These lower numbers are due to a high number of subjects (50 - 54%) reporting their pain value during these three injection phases at none, or 0 on the VAS. The majority of Stanley et al.’s placebo group experienced mild or moderate pain as described by the VAS report with 96%, 96%, and 86% for insertion, placement, and deposition phases, respectively (66). The prevalence of these mild and moderate
pain values from previous studies examining injection pain of the inferior alveolar block are certainly commensurate with values found in this study’s evaluation of the Gow-Gates and Vazirani-Akinosi techniques in a similar patient population. Most recently, in Fullmer’s thesis concerning premedication of symptomatic irreversible pulpitis with hydrocodone, the placebo group experienced mean VAS ratings of 73.0 ± 36.1 mm and 74.6 ± 37.3 mm for insertion and placement, respectively (48), whereas the current study showed smaller values, 44.2 ± 30.6 mm for insertion and 63.2 ± 31.3 mm for placement concerning the Gow-Gates injection and 46.9 ± 36.8 mm for insertion and 56.4 ± 41.0 mm for placement concerning the Vazirani-Akinosi injection. These values all fall within a mild-to-moderate categorization on the VAS, reinforcing the similarity in pain experienced among symptomatic irreversible pulpitis patients receiving a conventional inferior alveolar block and those receiving either a Gow-Gates or Vazirani-Akinosi injection.

Table 10 illustrates the failure point of anesthesia, or when subjects felt moderate to severe pain during treatment, in either the Gow-Gates or the Vazirani-Akinosi group. This failure point was in dentin for the majority of subjects after the IAN block. Among subjects receiving the Gow-Gates technique, 43% reported moderate to severe pain in dentin after the initial block injection and 79% of Vazirani-Akinosi subjects reported moderate to severe pain in dentin after the initial block injection. This study’s Gow-Gates group compares favorably to previous studies such as Simpson, Oleson, Stanley, Matthews, and Fullmer’s placebo groups receiving a conventional IANB, in which 34-49% of subjects failed while the operator was in dentin (44, 45, 48, 57, 66). The Vazirani-Akinosi group’s numbers are much higher at 79% but this is because the sample
size of this group (N = 38) created an underpowered statistical comparison. After an articaine infiltration, the majority of patients again failed in dentin: 23% in the Gow-Gates group and 38% in the Vazirani-Akinosi group. Once the first intraosseous injection was given, 11% of the subjects in the Gow-Gates group failed in dentin, an equivalent percentage failed during canal instrumentation. After the first intraosseous injection, the Vazirani-Akinosi group again showed a majority of subjects noting moderate to severe pain in dentin (26%). After a second intraosseous injection, the majority of subjects in the Vazirani-Akinosi group (43%) failed upon access into the pulp chamber. These numbers are important because it shows that with failures occurring primarily in dentin, the intrapulpal technique cannot be utilized. The buccal infiltration and intraosseous injection are excellent tools with which to create at least enough pulpal anesthesia to access the chamber, thereby allowing administration of an intrapulpal injection to complete anesthesia if necessary. Studies such as Oleson, Simpson, Stanley, and Fullmer substantiate this point with failure in dentin occurring 31-42% of the time after a buccal infiltration of articaine and 0-6% after an intraosseous injection (44, 45, 48, 66). Without the intraosseous injection, it can be seen from this investigation’s results as well as those of others, that access and instrumentation of pulpal nerve tissue would not be possible without inflicting at least moderate and as much as severe pain to patients diagnosed with symptomatic irreversible pulpitis.

Table 11 shows the subjects’ post-treatment remembered maximum pain. Patients were asked to recall the level of the most pain felt during treatment on a 170 mm VAS. No statistically significant difference was noted between the two groups (p = 0.0542). The p value is close to significance here because of the increased numbers of
females over males in the study as well as the smaller sample size of the Vazirani-Akinosi group. In fact, Table 11 shows that if the responses are categorized according to males and females, both groups do not show a statistically significant difference, however $p = 0.7515$ among male responses and $p = 0.0606$ for female responses. It is interesting to note that females had lower rates of remembered pain than males in both the Gow-Gates and Vazirani-Akinosi groups. In the Gow-Gates group, females noted a mean remembered pain value of $51.3 \pm 43.5$ mm on the VAS whereas males noted a $73.6 \pm 47.3$ mm ranking. In the Vazirani-Akinosi group women females reported a slightly lower mean of $74.7 \pm 49.6$ mm ranking than males who ranked their remembered pain of the Vazirani-Akinosi with a mean of $79.0 \pm 50.6$ mm. Females may have a lower remembered pain value than males in this study due to the gender of the operator. Though gendered operator-patient interaction is a characteristically multi-faceted topic whose complete consequences are not possible to address in the scope of this thesis, it is possible that females participating in this study developed a rapport with the female operator that resulted in lower remembered pain scores than that of the male participants.

In comparison, Lindemann et al.’s placebo group ($N = 17$) reported a remembered pain of $45.29 \pm 47.98$ mm (47). This compares favorably to the female Gow-Gates subjects’ reported remembered pain, but is lower than the remembered pain values of the male Gow-Gates subjects, and both male and female Vazirani-Akinosi subjects. A comparison between Lindemann’s study and this investigation is difficult due to small sample sizes, $N = 17$ in Lindemann’s study encompassing both sexes and $N= 17$ in both male groups (Gow-Gates and Vazirani-Akinosi) and $N = 21$ in the female Vazirani-Akinosi group in this investigation. Furthermore, patients in Lindemann’s study who had been
premedicated with triazolam noted even higher remembered pain than the placebo group (66.32 ± 44.95 mm), which may indicate an inherent variability of subjects’ responses when asked to report post-treatment remembered maximum pain.

Finally, Table 12 illustrates subjects’ post-treatment satisfaction ratings. No significant difference was noted among subjects receiving the Gow-Gates or the Vazirani-Akinosi injection for emergency endodontic treatment. Patients were asked to scale their satisfaction with treatment on a 100 mm scale where 0 mm indicated, “not satisfied” and ≥ 66 mm to 100 mm indicated, “completely satisfied.” All patients in the Gow-Gates group reported at least moderate satisfaction with the majority (95%) reporting complete satisfaction. The mean satisfaction rating for the Gow-Gates group was found to be 93.7 ± 12.5 mm. The majority of the Vazirani-Akinosi group reported at least a moderately satisfied ranking with 94% stating complete satisfaction. The overall findings in this study are commensurate with other studies such as Stanley et al. whose placebo group noted a 96 mm rating and Fullmer et al.’s placebo group who noted a 88.7 mm mean rating (48, 66). The significance of a high satisfaction rating with treatment is clinically important. It affirms that despite the experience of moderate to severe pain during treatment, subjects (and clinical patients) will accept this level of pain if they feel they are being treated well and attended to with compassion.
The purpose of the present study was to evaluate two alternative inferior alveolar block injections, the Gow-Gates and the Vazirani-Akinosi techniques, in assessing whether either technique would increase the success rate of mandibular anesthesia in patients diagnosed with symptomatic irreversible pulpitis in a mandibular posterior tooth. Past studies have reported various findings relating to enhanced anesthesia obtained from these techniques in a range of patient populations (23, 71, 74, 75, 77-79, 81-91). Few studies have examined these injections in a moderate-to-severe endodontic pain model (89, 90). It was hypothesized in the present study that the Gow-Gates and Vazirani-Akinosi injections would provide a commensurate level of pulpal anesthesia as the conventional inferior alveolar block in patients presenting with moderate to severe pain due to a mandibular posterior tooth diagnosed with symptomatic irreversible pulpitis.

The block success of the Vazirani-Akinosi injection was found to be 63%, indicating that this technique may not deliver clinically acceptable results for routine endodontic treatment. The block success rate for the Gow-Gates injection was 92%. Among patients who achieved block success, the pulpal anesthesia success rate for the
Gow-Gates group was 35% and the success rate for the Vazirani-Akinosi group was 16%. The pulpal success rate of the Gow-Gates technique is commensurate with those obtained by the conventional inferior alveolar nerve block. For this reason, this study neither advocates nor opposes the use of the Gow-Gates technique over the conventional inferior alveolar nerve block. The block and pulpal success rates of the Vazirani-Akinosi technique are clinically unacceptable therefore the technique is not recommended for anesthesia in routine endodontic treatment of patients with symptomatic irreversible pulpitis of a mandibular posterior tooth.
APPENDIX A

TABLES
<table>
<thead>
<tr>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>---</td>
<td>---:</td>
</tr>
<tr>
<td>Age (years)</td>
<td>60</td>
</tr>
<tr>
<td>Male</td>
<td>17</td>
</tr>
<tr>
<td>Female</td>
<td>43</td>
</tr>
<tr>
<td>Initial Pain mm**</td>
<td>60</td>
</tr>
<tr>
<td>Male</td>
<td>17</td>
</tr>
<tr>
<td>Female</td>
<td>43</td>
</tr>
</tbody>
</table>

* Values analyzed using the Randomization test.
** Heft-Parker Visual Analog Scale (170 mm).

Table 1. Age, Gender, and Initial Pain.

<table>
<thead>
<tr>
<th></th>
<th>4-8 Low Anxiety</th>
<th>9-12 Moderate Anxiety</th>
<th>13-14 High Anxiety</th>
<th>15-20 Severe Anxiety</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gow Gates</td>
<td>25 (42%)</td>
<td>18 (30%)</td>
<td>6 (10%)</td>
<td>11 (18%)</td>
<td>0.3007</td>
</tr>
<tr>
<td>Median ± SD:</td>
<td>9.0 ± 4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = 60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male: 10.2 ± 4.3</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>4</td>
<td>0.8081</td>
</tr>
<tr>
<td>Female: 9.9 ± 3.9</td>
<td>20</td>
<td>11</td>
<td>5</td>
<td>7</td>
<td>0.1097</td>
</tr>
<tr>
<td>Vazirani-Akinosi</td>
<td>12 (32%)</td>
<td>14 (37%)</td>
<td>6 (16%)</td>
<td>6 (16%)</td>
<td></td>
</tr>
<tr>
<td>Median: 10.5 ± 4.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = 38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male: 9.7 ± 3.2</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Female: 11.8 ± 4.6</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

* Values analyzed using the Mann-Whitney-Wilcoxon test.

Table 2. Initial Corah’s Dental Anxiety Scale Ratings.
**Table 3. Initial Analysis by Tooth Type and Gender.**

<table>
<thead>
<tr>
<th>Tooth Type</th>
<th>Gow-Gates (N = 60)</th>
<th>Vazirani-Akinosi (N = 38)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>1st Molar</td>
<td>37</td>
<td>62</td>
<td>22</td>
</tr>
<tr>
<td>2nd Molar</td>
<td>21</td>
<td>35</td>
<td>16</td>
</tr>
<tr>
<td>2nd Premolar</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td>Male: 17</td>
</tr>
</tbody>
</table>

*Values analyzed using a Fisher Exact test.
**Value analyzed using a Chi-square test.

**Table 4. Lip and Pulpal Anesthetic Success.**

<table>
<thead>
<tr>
<th></th>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Subjects</td>
<td>65</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Lip Numbness (%)</td>
<td>60 (92%)</td>
<td>38 (63%)</td>
<td>*<em>0.0002</em></td>
</tr>
<tr>
<td>Pulpal Anesthesia</td>
<td>21 (35%)</td>
<td>6 (16%)</td>
<td>*<em>0.0381</em></td>
</tr>
</tbody>
</table>

*Values analyzed using the Chi-Square test.
†N for the Gow-Gates is 65, N for the Vazirani-Akinosi is 60.
‡N for the Gow-Gates is 60, N for the Vazirani-Akinosi is 38.
<table>
<thead>
<tr>
<th>IANB SUCCESS</th>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>39/60</td>
<td>65</td>
</tr>
<tr>
<td>Yes</td>
<td>21/60</td>
<td>35</td>
</tr>
</tbody>
</table>

Articaine Infiltration SUCCESS

<table>
<thead>
<tr>
<th>SUCCESS</th>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>19/39</td>
<td>49</td>
</tr>
<tr>
<td>Yes</td>
<td>20/39</td>
<td>51</td>
</tr>
</tbody>
</table>

IO #1 SUCCESS

<table>
<thead>
<tr>
<th>SUCCESS</th>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>5/19</td>
<td>26</td>
</tr>
<tr>
<td>Yes</td>
<td>14/19</td>
<td>74</td>
</tr>
</tbody>
</table>

IO #2 SUCCESS

<table>
<thead>
<tr>
<th>SUCCESS</th>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>1/4</td>
<td>25</td>
</tr>
<tr>
<td>Yes</td>
<td>3/4</td>
<td>75</td>
</tr>
</tbody>
</table>

*Values analyzed using the Chi-Square test
**Value analyzed using the Fisher Exact test

**Table 5. Pulpal Anesthetic Success of Block Injection, Articaine Infiltration, and Intraosseous (IO) Injections.**
<table>
<thead>
<tr>
<th>Block Pulpal Anesthetic SUCCESS</th>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>No Female</td>
<td>26</td>
<td>60</td>
</tr>
<tr>
<td>Yes Female</td>
<td>17</td>
<td>40</td>
</tr>
<tr>
<td>No Male</td>
<td>13</td>
<td>76</td>
</tr>
<tr>
<td>Yes Male</td>
<td>4</td>
<td>24</td>
</tr>
</tbody>
</table>

*Values analyzed using the Chi-Square test.
** Values analyzed using the Fisher Exact test.

Table 6. Pulpal Anesthetic Success of the Block Injections by Gender.
<table>
<thead>
<tr>
<th>Group</th>
<th>Stage</th>
<th>N</th>
<th>Mean</th>
<th>STD</th>
<th>Min</th>
<th>Max</th>
<th>P (adj)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>GG</td>
<td>INS</td>
<td>59</td>
<td>44.2</td>
<td>30.6</td>
<td>0</td>
<td>115</td>
<td>1.0000</td>
</tr>
<tr>
<td>GG</td>
<td>PLC</td>
<td>59</td>
<td>63.2</td>
<td>31.3</td>
<td>3</td>
<td>122</td>
<td>1.0000</td>
</tr>
<tr>
<td>GG</td>
<td>DEP</td>
<td>60</td>
<td>66.8</td>
<td>36.5</td>
<td>0</td>
<td>154</td>
<td>1.0000</td>
</tr>
<tr>
<td>VA</td>
<td>INS</td>
<td>38</td>
<td>46.9</td>
<td>36.8</td>
<td>0</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>VA</td>
<td>PLC</td>
<td>38</td>
<td>56.4</td>
<td>41.0</td>
<td>0</td>
<td>143</td>
<td></td>
</tr>
<tr>
<td>VA</td>
<td>DEP</td>
<td>38</td>
<td>65.0</td>
<td>38.2</td>
<td>4</td>
<td>161</td>
<td></td>
</tr>
</tbody>
</table>

* Unreported insertion and placement from one patient in the GG group.
** Values analyzed using the step-down Bonferroni method of Holm.

Table 7. Pain of Gow-Gates (GG) and Vazirani-Akinosi (VA) Injections by Stage Using the Heft-Parker Visual Analog Scale (mm).
(INS = needle insertion, PLC = needle placement, DEP = solution deposition)

<table>
<thead>
<tr>
<th>Gow-Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>INS</td>
<td>42*</td>
</tr>
<tr>
<td>PLC</td>
<td>42*</td>
</tr>
<tr>
<td>DEP</td>
<td>43</td>
</tr>
<tr>
<td>Male</td>
<td></td>
</tr>
<tr>
<td>INS</td>
<td>17</td>
</tr>
<tr>
<td>PLC</td>
<td>17</td>
</tr>
<tr>
<td>DEP</td>
<td>17</td>
</tr>
</tbody>
</table>

* Unreported insertion and placement from one patient in the GG group.
** Values analyzed using the Step-down Bonferroni method of Holm.

Table 8. Pain of Gow-Gates (GG) and Vazirani-Akinosi (VA) Injections by Stage Using the Heft-Parker Visual Analog Scale (mm) by Gender.
(INS = needle insertion, PLC = needle placement, DEP = solution deposition)
<table>
<thead>
<tr>
<th>Group</th>
<th>Injection Stage</th>
<th>N</th>
<th>None (0 mm *)</th>
<th>Mild (&gt;0 mm, ≤54 mm *)</th>
<th>Moderate (&gt;54 mm, &lt;114 mm *)</th>
<th>Severe (≥114 mm *)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gow-Gates:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INS</td>
<td>59</td>
<td>3 (13%)</td>
<td>34 (58%)</td>
<td>21 (36%)</td>
<td>1 (2%)</td>
<td></td>
</tr>
<tr>
<td>PLC</td>
<td>59</td>
<td>0 (0%)</td>
<td>25 (42%)</td>
<td>31 (53%)</td>
<td>3 (5%)</td>
<td></td>
</tr>
<tr>
<td>DEP</td>
<td>60</td>
<td>1 (2%)</td>
<td>20 (33%)</td>
<td>34 (57%)</td>
<td>5 (8%)</td>
<td></td>
</tr>
<tr>
<td>Vazirani-Akinosi:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INS</td>
<td>38</td>
<td>4 (11%)</td>
<td>21 (55%)</td>
<td>11 (29%)</td>
<td>2 (5%)</td>
<td></td>
</tr>
<tr>
<td>PLC</td>
<td>38</td>
<td>4 (11%)</td>
<td>14 (37%)</td>
<td>15 (39%)</td>
<td>5 (13%)</td>
<td></td>
</tr>
<tr>
<td>DEP</td>
<td>38</td>
<td>0 (0%)</td>
<td>14 (37%)</td>
<td>20 (53%)</td>
<td>4 (11%)</td>
<td></td>
</tr>
</tbody>
</table>

* Heft-Parker Visual Analog Scale (170 mm).

Table 9. Pain of Gow-Gates (GG) and Vazirani-Akinosi (VA) Injections by Stage Using Categorical values of the Heft-Parker Visual Analog Scale.
<table>
<thead>
<tr>
<th>Anesthetic Failure Point</th>
<th>Gow Gates</th>
<th>Vazirani-Akinosi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Block</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>21/60 (35%)</td>
<td>6/38 (16%)</td>
</tr>
<tr>
<td>Dentin</td>
<td>26/60 (43%)</td>
<td>30/38 (79%)</td>
</tr>
<tr>
<td>Chamber</td>
<td>10/60 (17%)</td>
<td>1/38 (3%)</td>
</tr>
<tr>
<td>Canals</td>
<td>3/60 (5%)</td>
<td>1/38 (3%)</td>
</tr>
<tr>
<td><strong>Articaine Infiltration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>20/39 (51%)</td>
<td>12/32 (38%)</td>
</tr>
<tr>
<td>Dentin</td>
<td>9/39 (23%)</td>
<td>12/32 (38%)</td>
</tr>
<tr>
<td>Chamber</td>
<td>6/39 (15%)</td>
<td>5/32 (16%)</td>
</tr>
<tr>
<td>Canals</td>
<td>4/39 (10%)</td>
<td>3/32 (9%)</td>
</tr>
<tr>
<td><strong>I/O1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>14/19 (74%)</td>
<td>11/19 (58%)</td>
</tr>
<tr>
<td>Dentin</td>
<td>2/19 (11%)</td>
<td>5/19 (26%)</td>
</tr>
<tr>
<td>Chamber</td>
<td>1/19 (5%)</td>
<td>2/19 (11%)</td>
</tr>
<tr>
<td>Canals</td>
<td>2/19 (11%)</td>
<td>1/19 (5%)</td>
</tr>
<tr>
<td><strong>I/O2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2/4 (50%)</td>
<td>2/7 (29%)</td>
</tr>
<tr>
<td>Dentin</td>
<td>1/4 (25%)</td>
<td>2/7 (29%)</td>
</tr>
<tr>
<td>Chamber</td>
<td>1/4 (25%)</td>
<td>3/7 (43%)</td>
</tr>
<tr>
<td>Canals</td>
<td>0/4 (0%)</td>
<td>0/7 (0%)</td>
</tr>
</tbody>
</table>

Table 10. Anesthetic Failure Point and Patient Distribution.
<table>
<thead>
<tr>
<th>Group (mean ± SD) mm</th>
<th>None (0 mm **)</th>
<th>Mild (&gt;0 mm, ≤54 mm **)</th>
<th>Moderate (&gt;54 mm, &lt;114 mm **)</th>
<th>Severe (≥114 mm **)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gow-Gates:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 57.6 ± 45.3</td>
<td>7 (12%)</td>
<td>22 (37%)</td>
<td>23 (38%)</td>
<td>8 (13%)</td>
<td>0.0542*</td>
</tr>
<tr>
<td>N = 60 (min=0, max=165 **)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 73.6 ± 47.3</td>
<td>1 (6%)</td>
<td>6 (35%)</td>
<td>6 (35%)</td>
<td>4 (24%)</td>
<td>0.7515*</td>
</tr>
<tr>
<td>(min=0, max=165 **)</td>
<td></td>
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<td></td>
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<tr>
<td>N = 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 51.3 ± 43.5</td>
<td>6 (14%)</td>
<td>16 (37%)</td>
<td>17 (40%)</td>
<td>4 (11%)</td>
<td>0.0606*</td>
</tr>
<tr>
<td>(min=0, max=140 **)</td>
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<td>N = 43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vazirani-Akinosi:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 76.6 ± 49.4</td>
<td>1 (3%)</td>
<td>12 (32%)</td>
<td>13 (34%)</td>
<td>12 (32%)</td>
<td></td>
</tr>
<tr>
<td>N = 38 (min=0, max=156 **)</td>
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<td></td>
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</tr>
<tr>
<td>Male:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 79.0 ± 50.6</td>
<td>1 (6%)</td>
<td>4 (24%)</td>
<td>5 (29%)</td>
<td>7 (41%)</td>
<td></td>
</tr>
<tr>
<td>(min=0, max=153 **)</td>
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<tr>
<td>N = 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 74.7 ± 49.6</td>
<td>0 (0%)</td>
<td>8 (38%)</td>
<td>7 (33%)</td>
<td>6 (29%)</td>
<td></td>
</tr>
<tr>
<td>(min=2, max=156 **)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>N = 21</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Values analyzed using Randomization tests.

** Heft-Parker Visual Analog Scale (170 mm).

Table 11. Patient Post-Treatment Remembered Maximum Pain.
<table>
<thead>
<tr>
<th>Group (mean ± SD) mm</th>
<th>Not Satisfied</th>
<th>Somewhat Satisfied</th>
<th>Moderately Satisfied</th>
<th>Completely Satisfied</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gow-Gates:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 93.7 ± 12.5</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>3 (5%)</td>
<td>57 (95%)</td>
<td>0.4721*</td>
</tr>
<tr>
<td>N = 60 (min=49, max=100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vazirani-Akinosi:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean: 91.3 ± 18.9</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
<td>1 (3%)</td>
<td>35 (94%)</td>
<td></td>
</tr>
<tr>
<td>N = 37 ** (min=0, max=100)</td>
<td></td>
<td></td>
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</table>

*Values analyzed using Randomization tests.

** One Vazirani-Akinosi subject did not report satisfaction at all.

**Table 12. Patient Post-Treatment Satisfaction Ratings.**
APPENDIX B

GENERAL CONSENT FORM
The Ohio State University Consent to Participate in Research

Study Title: Efficacy of the Gow-Gates and Vazirani-Akinosi nerve blocks in patients with symptomatic irreversible pulpitis.

Principal Investigator: Dr. Melissa Drum

Sponsor:

• This is a consent form for research participation. It contains important information about this study and what to expect if you decide to participate. Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to participate.

• Your participation is voluntary. You may refuse to participate in this study. If you decide to take part in the study, you may leave the study at any time. No matter what decision you make, there will be no penalty to you and you will not lose any of your usual benefits. Your decision will not affect your future relationship with The Ohio State University. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status.

• You may or may not benefit as a result of participating in this study. Also, as explained below, your participation may result in unintended or harmful effects for you that may be minor or may be serious depending on the nature of the research.

• You will be provided with any new information that develops during the study that may affect your decision whether or not to continue to participate. If you decide to participate, you will be asked to sign this form and will receive a copy of the form. You are being asked to consider participating in this study for the reasons explained below.

1. Why is this study being done?
The purpose of this study is to see if the Gow-Gates or Vazirani-Akinosi injection improves the success of tooth numbness during emergency root canal treatment.

2. How many people will take part in this study?
One hundred and thirty (130) people will take part in this study.

3. What will happen if I take part in this study?
You have a tooth, which is hurting (painful), and you are aware that it needs a root canal. If you decide to participate in this study, you will be required to complete a medical history questionnaire, a HIPAA authorization and consent form. If you are a woman able to have children, you will be required to take a urine pregnancy test before participation.
The study requires one appointment but you will need at least one additional appointment to finish the root canal if you elect to save your tooth.

**The following part of the study is associated with the research.** Before your doctor starts your root canal, you will receive an injection to get you numb. The type of injection (Gow-Gates or Vazirani-Akinosi) will be chosen at random (by chance, like flipping a coin). You will not know which one you will receive. The purpose of this study is to see if one of these two types of injections gets you numb. You will be asked to rate the pain you are having prior to any treatment. You will also fill out a form to rate how anxious you are. You will be asked to rate the amount of pain you feel when the injection is being given. You will do this by marking your pain with a pencil on a line graph. Once root canal treatment is completed, you will be asked to rate your satisfaction with the treatment you received.

**The following procedures are needed for standard root canal treatment and will occur whether or not I take part in this study.** The tooth causing you pain will first be tested to insure an accurate diagnosis. It will first be tested with a cold cotton pellet chilled with an ice spray. Your tooth may hurt for a few moments after being tested with the cold. The cold pellet will be removed immediately after you feel the sensation in your tooth. The cold test is used routinely before root canal treatment.

One injection (shot) will be given in the back of your jaw to numb your lower teeth (inferior alveolar injection) using 2% lidocaine with 1:100,000 epinephrine which is an anesthetic (numbing solution) similar to novocaine. 2% lidocaine with 1:100,000 epinephrine has been used in the dental office and has been approved by the Food and Drug Administration. You will randomly receive one of two types of injections. One injection (shot) may require you to keep your mouth open after the injection (shot), the other injection (shot) may require you to stay closed during the injection (shot). Whichever injection (shot) you receive, it will be placed in the upper back corner of your mouth.

Following the anesthetic injection the doctor will begin asking you every minute for 20 minutes whether you are experiencing lip numbness. At 20 minutes if your lip is not numb, you will be given extra anesthesia (shots). Next, a small opening will be made in the top of your tooth to begin the root canal. If you feel pain, you will raise your hand and will be asked to rate the pain. If you have moderate or severe pain, a supplemental (extra) injection (shot) of 4% articaine with 1:100,000 epinephrine will then be given directly beside your tooth (under the gums). This may be uncomfortable. Routine emergency root canal treatment will then be completed.

Your participation or non-participation will have no effect on whether you will receive emergency root canal treatment. You understand that if you want to save the treated tooth (provided it is restorable or savable) further root canal treatment and restorative treatment such as a filling and or a crown will be needed. You are responsible for the emergency root canal fee.
4. **How long will I be in the study?**
   You are aware that you will have one appointment, which will last approximately 120 minutes.

5. **Can I stop being in the study?**
   You may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

6. **What risks, side effects or discomforts can I expect from being in the study?**
   You may have pain associated with the local anesthetic (numbing solution) or soreness at the site of the injections (shots) for approximately two days. Where you receive the injection, you may have swelling (hematoma—a collection of blood in your mouth) or a bruise may develop. You may experience a feeling of anxiety, lightheadedness or fainting, and or a temporary increase in your heart rate. The tingling sensation and/or slight discomfort (pain) produced by the cold ice spray may be uncomfortable to you. You may have an allergic reaction to the local anesthetic (itching or hives, very rare), or have an unexpected infection (rare) which could result in permanent nerve damage. You may have soreness of your gum tissue for a few days or a possible altered sensation of your lip or tongue that may last up to a few weeks. Your tooth may feel sore to bite on for a few days. All of these risks can be expected if you have root canal treatment without participating in the study.

   If you are a woman able to have children, you will be questioned regarding pregnancy or suspected pregnancy and will not be allowed to participate if pregnant, suspect a pregnancy, or trying to become pregnant. Additionally, you will be required to take a urine pregnancy test before you can start this study. The reason for excluding pregnant or potentially pregnant women is an attempt to minimize this population in the study due to the extended supine positioning required for the Gow-Gates injection. Pregnant patients could have difficulty maintaining a supine position for extended periods of time as required for the Gow-Gates injection.

7. **What benefits can I expect from being in the study?**
   You will not directly benefit from this study except for the $75.00 paid to you for your participation.

8. **What other choices do I have if I do not take part in the study?**
   You may have the emergency endodontic procedure completed without having one of these two types of injections administered. You will get a third type of injection instead. You may choose not to participate without penalty or loss of benefits to which you are otherwise entitled.
9. **Will my study-related information be kept confidential?**
Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law.

Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- U.S. Food and Drug Administration;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor supporting the study, their agents or study monitors; and
- Your insurance company (if charges are billed to insurance).

If this study is related to your medical care, your study-related information may be placed in your permanent hospital, clinic, or physician’s office records. Authorized Ohio State University staff not involved in the study may be aware that you are participating in a research study and have access to your information.

You may also be asked to sign a separate Health Insurance Portability and Accountability Act (HIPAA) research authorization form if the study involves the use of your protected health information.

10. **What are the costs of taking part in this study?**
Because routine endodontic treatment will be performed, other costs (emergency fees, parking) will not be reimbursed in this study. The study will pay for the cost of the urine pregnancy test.

11. **Will I be paid for taking part in this study?**
Yes, you will be paid $75.00 for your participation.

By law, payments to subjects are considered taxable income.

12. **What happens if I am injured because I took part in this study?**
If you suffer an injury from participating in this study, you should notify the researcher or study doctor immediately, who will determine if you should obtain medical treatment at The Ohio State University Medical Center.

The cost for this treatment will be billed to you or your medical or hospital insurance. The Ohio State University has no funds set aside for the payment of health care expenses for this study.
13. What are my rights if I take part in this study?
If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights you may have as a participant in this study.

You will be provided with any new information that develops during the course of the research that may affect your decision whether or not to continue participation in the study.

You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

14. Who can answer my questions about the study?
For questions, concerns, or complaints about the study you may contact Dr. Melissa Drum or Dr. Vivian Click at 614 – 292-5399.

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact Dr. Melissa Drum or Dr. Vivian Click at 614-292-5399.
Signing the consent form

I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

<table>
<thead>
<tr>
<th>Printed name of subject</th>
<th>Signature of subject</th>
<th>AM/PM</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Date and time</td>
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</table>

<table>
<thead>
<tr>
<th>Printed name of person authorized to consent for subject (when applicable)</th>
<th>Signature of person authorized to consent for subject (when applicable)</th>
<th>AM/PM</th>
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<tbody>
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Investigator/Research Staff

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

<table>
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<tr>
<th>Printed name of person obtaining consent</th>
<th>Signature of person obtaining consent</th>
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Witness(es) - *May be left blank if not required by the IRB*

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<th>Signature of witness</th>
<th>AM/PM</th>
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<tbody>
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</thead>
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<tr>
<td></td>
<td>Date and time</td>
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APPENDIX C

PATIENT PRIVACY FORM
Title of the Study: Efficacy of the Gow-Gates and Vazirani-Akinosi nerve blocks in patients with symptomatic irreversible pulpitis.

OSU Protocol Number:

Principal Investigator: Dr. Melissa Drum DDS, MS

Subject Name__________________________________________________________

Before researchers use or share any health information about you as part of this study, The Ohio State University is required to obtain your authorization. This helps explain to you how this information will be used or shared with others involved in the study.

• The Ohio State University and its hospitals, clinics, health-care providers and researchers are required to protect the privacy of your health information.

• You should have received a Notice of Privacy Practices when you received health care services here. If not, let us know and a copy will be given to you. Please carefully review this information. Ask if you have any questions or do not understand any parts of this notice.

• If you agree to take part in this study your health information will be used and shared with others involved in this study. Also, any new health information about you that comes from tests or other parts of this study will be shared with those involved in this study.

• Health information about you that will be used or shared with others involved in this study may include your research record and any health care records at the Ohio State University. For example, this may include your medical records, x-ray or laboratory results. Psychotherapy notes in your health records (if any) will not, however, be shared or used. Use of these notes requires a separate, signed authorization.

Please read the information carefully before signing this form. Please ask if you have any questions about this authorization, the University’s Notice of Privacy Practices or the study before signing this form.

Initials/Date: _______________
Those Who May Use, Share And Receive Your Information As Part Of This Study

- Researchers and staff at The Ohio State University will use, share and receive your personal health information for this research study. Authorized Ohio State University staff not involved in the study may be aware that you are participating in a research study and have access to your information. If this study is related to your medical care, your study-related information may be placed in your permanent hospital, clinic or physician’s office records.

- Those who oversee the study will have access to your information, including:
  - Members and staff of the Ohio State University’s Institutional Review Boards, including the Western Institutional Review Board
  - The Office for Responsible Research Practices
  - University data safety monitoring committees
  - The Ohio State University Research Foundation

- Your health information may also be shared with federal and state agencies that have oversight of the study or to whom access is required under the law. These may include:
  - The Food and Drug Administration
  - The Office for Human Research Protections
  - The National Institutes of Health
  - The Ohio Department of Job and Family Services

These researchers, companies and/or organization(s) outside of The Ohio State University may also use, share and receive your health information in connection with this study:

- None

The information that is shared with those listed above may no longer be protected by federal privacy rules.

Initials/Date_________

Page 2 of 3
Authorization Period
This authorization will not expire unless you change your mind and revoke it in writing. There is
no set date at which your information will be destroyed or no longer used. This is because the
information used and created during the study may be analyzed for many years, and it is not
possible to know when this will be complete.

Signing the Authorization
• You have the right to refuse to sign this authorization. Your health care outside of the study,
  payment for your health care, and your health care benefits will not be affected if you choose
  not to sign this form.
• You will not be able to take part in this study and will not receive any study treatments if you
do not sign this form.
• If you sign this authorization, you may change your mind at any time. Researchers may
  continue to use information collected up until the time that you formally changed your mind.
  If you change your mind, your authorization must be revoked in writing. To revoke your
  authorization, please write to:
  Dr. Melissa Drum at the College of Dentistry, 305 W. 12th avenue, the Ohio State University,
  Columbus, Ohio 43210 or Dr. Henry Fischbach at the College of Dentistry, 305 W. 12th
  avenue, the Ohio State University, Columbus, Ohio 43210.
• Signing this authorization also means that you will not be able to see or copy your study-
  related information until the study is completed. This includes any portion of your medical
  records that describes study treatment.

Contacts for Questions
• If you have any questions relating to your privacy rights, please contact Dr. Henry Fischbach
  at the College of Dentistry, 305 W 12th avenue, the Ohio State University, Columbus, Ohio
  43210.
• If you have any questions relating to the research, please contact Dr. Melissa Drum at the
  College of Dentistry, 305 W. 12th avenue, the Ohio State University, Columbus, Ohio 43210.

Signature
I have read (or someone has read to me) this form and have been able to ask questions. All of my
questions about this form have been answered to my satisfaction. By signing below, I permit Dr.
Melissa Drum and the others listed on this form to use and share my personal health information
for this study. I will be given a copy of this signed form.

Signature________________________________________________________
(Subject or Legally Authorized Representative)

Name _____________________________________________________________
(Print name above)
(If legal representative, also print relationship to subject.)

Date___________ Time __________ AM / PM
APPENDIX D

HEALTH HISTORY QUESTIONNAIRE
Medical History

1. Do you have or have you had any of the following?
   a. rheumatic fever or rheumatic heart disease………………. NO YES
   b. heart murmur or mitral valve prolapse……………………. NO YES
   c. heart disease or heart attack……………………………… NO YES
   d. artificial heart valve……………………………………….. NO YES
   e. irregular heart beat………………………………………… NO YES
   f. pacemaker…………………………………………………… NO YES
   g. high blood pressure………………………………………… NO YES
   h. chest pains or angina……………………………………….. NO YES
   i. stroke…………………………………………………………. NO YES
   j. artificial joint………………………………………………... NO YES
   k. hepatitis/liver disease……………………………………… NO YES
   l. tuberculosis………………………………………………….. NO YES
   m. thyroid problem…………………………………………….. NO YES
   n. kidney disease……………………………………………… NO YES
   o. diabetes (sugar)……………………………………………… NO YES
   p. asthma………………………………………………………… NO YES
   q. HIV or other immunosuppressive disease………………….. NO YES
   r. radiation or cancer therapy…………………………………. NO YES

2. Do you or have you had any disease, condition, or problem not listed here? NO YES

3. Have you ever been hospitalized? NO YES

4. Have you had excessive or prolonged bleeding requiring special treatment? NO YES

5. Have you had an allergic reaction to any drugs or medications?
   (Circle all that apply: penicillin; codeine; aspirin; anesthetics; other) NO YES

6. Are you currently under the care of a physician (M.D., D.O.)? NO YES
   When were you last seen by a physician?____________________
   Name of Physician_______________________________________
   Street address___________________________________________
   City, State, and Zip Code__________________________________
   Phone__________________________________________________

7. Are you pregnant or nursing? Estimated date of delivery___________ NO YES

8. Have you had any trouble associated with previous dental treatment? NO YES

9. How often do you have dental check ups? ___________ Date of last Exam___________

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10. Do you have any lumps or sores in your mouth now?  
   NO  YES

11. Do you smoke or use smokeless tobacco?  
   NO  YES

12. Are you currently taking any drugs or medications  
    (such as antibiotics, heart medicine, birth control pills?)  
   NO  YES

**Current Medications**

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<th>Generic Name</th>
<th>Dose/Frequency</th>
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**Summary of Patient’s Medical Status:**

____________________________________________________________________________

____________________________________________________________________________

**Medical Risk Assessment**

ASA I (healthy individual)  ASA III (severe disease but not incapacitating)
ASA II (mild systemic disease)  ASA IV (incapacitating systemic disease)

**Medical Consultation Required**

No (healthy and/or stabilized disease)

Yes (ASA III or IV; cardiac murmur; vague hx; recent major disease; recent  
    diagnosis/operation; uncontrolled disease; blood pressure; etc.)

To the best of my knowledge, the above information is correct and complete.

________________________________________  _______________________
Patient’s Signature                     Date
APPENDIX E

CORAH’S DENTAL ANXIETY QUESTIONNAIRE
Patient #: ___________________

Date: _______________  Code #: ___________________

For each question, please circle the letter (and only one letter) that best approximates how you feel.

1. If you had to go to the dentist tomorrow, how would you feel about it?

   a) I would look forward to it as a reasonably enjoyable experience.
   b) I wouldn’t care one way or the other.
   c) I would be a little uneasy about it.
   d) I would be afraid that it would be unpleasant and painful.
   e) I would be very frightened of what the dentist might do.

2. When you are waiting in the dentist’s office for your turn in the chair, how do you feel?

   a) Relaxed.
   b) A little uneasy.
   c) Tense.
   d) Anxious.
   e) So anxious that I sometimes break out in a sweat or almost feel physically sick.

3. When you are in the dentist’s chair waiting while he gets his drill ready to begin working on your teeth, how do you feel?

   a) Relaxed.
   b) A little uneasy.
   c) Tense.
   d) Anxious.
   e) So anxious that I sometimes break out in a sweat or almost feel physically sick.

4. You are in the dentist’s chair to have your teeth cleaned. While you are waiting and the dentist is getting out the instruments, which he will use to scrape your teeth around the gums, how do you feel?

   a) Relaxed.
   b) A little uneasy.
   c) Tense.
   d) Anxious.
   e) So anxious that I sometimes break out in a sweat or almost feel physically sick.
APPENDIX F

HEFT-PARKER VISUAL ANALOG SCALE
0-54 mm …… Mild pain

55-113 mm .... Moderate Pain

114-170 mm … Severe Pain
APPENDIX G

PATIENT POST-TREATMENT SATISFACTION SCALE
Date:____________________

Code #:____________________

Satisfaction Rating

Mark a vertical line “│” on the point on the scale line that best describes your satisfaction.

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Not Satisfied  Somewhat Satisfied  Moderately Satisfied  Completely Satisfied
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REFERENCES


