THE USE OF ULTRASONOGRAPHY IN DIFFERENTIATING CELLULITIS AND FLUCTUANT ODONTOGENIC SWELLINGS

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ABSTRACT

Determining whether an odontogenic swelling is a cellulitis or fluctuance is difficult but important as both may require different treatments. It has been suggested in the medical and dental literature that the use of an ultrasound may aid in differentiating cellulitis and fluctuance. Therefore, the purpose of this investigation was to compare the accuracy of clinical examination alone versus clinical examination plus ultrasonography in the diagnosis of cellulitis and fluctuant swellings in symptomatic patients with a diagnosis of pulpal necrosis, acute apical abscess or cellulitis, and clinical swelling. Eighty-two emergency patients participated in this study. Each patient was examined and diagnosed by clinical examination and by clinical examination plus ultrasonography. An incision for drainage procedure was performed and a definitive diagnosis was recorded. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated. With clinical exam alone, a correct diagnosis was made 56 of 82 times (68.3%). With clinical exam plus ultrasonography, a correct diagnosis was made 57 of 82 times (69.5%). The sensitivity of the clinical exam alone was 30% and for clinical exam plus ultrasonography it was 40%. The specificity was 90.4% for the clinical exam alone and 86.5% for the clinical
exam plus ultrasonography. The positive predictive values, negative predictive values, and accuracy values were 64.3% versus 63.2%, 69.1% versus 71.4%, and 68.3% versus 69.5% for clinical exam alone versus clinical exam plus ultrasonography, respectively. In conclusion, the addition of ultrasonography to clinical exam alone did not significantly increase the number of correct diagnoses made.
DEDICATION

To my husband, Thad, for his endless love and support. Even during the tough times, you are always by my side. You are the most caring and selfless person. You make me laugh every day and I look forward to our journey together. You truly are my best friend and I love you more than you know.

To my father, Phil, and my brother, Philip, for constantly supporting me and believing in me. Thank you for always listening to me and helping me through the tough times. I love you both so much.

In memory of my beloved mother, Jacquelyn, and my Aunt Delma. Not a day goes by where I do not think about you and wish you were here. I carry you with me always. I am the person I am today because of you.
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CHAPTER 1

INTRODUCTION

Odontogenic infections represent a significant amount of the dental problems that present to hospital emergency departments (ED). Lewis et al. (1) compiled data from the 1997-2000 National Hospital Ambulatory Medical Care Survey to determine national estimates of counts and rates of ED visits for dental-related complaints. They estimated that 2.95 million ED visits in the United States were for complaints of tooth pain or tooth injury, for an average of 738,000 visits annually. The visits for dental complaints were highest in the 19- to 35-year-old group which accounted for 1.3% of all emergency visits. Dental caries, pulp, and periapical infections comprised 43% of the discharge diagnoses assigned to visits for dental complaints making it the second most frequently listed category behind “dental problem not otherwise specified” (1).

Determining whether a soft tissue infection is an abscess (fluctuance) or cellulitis may be difficult clinically, but is very important as both may require different treatments (2-4). “Swellings may be localized or diffuse, fluctuant or firm” (5). A fluctuant swelling is localized and characterized by the sensation on palpation that there is fluid movement under the tissue, indicating pus is present. A swelling that spreads through adjacent soft tissue and dissects tissue spaces along
fascial planes is considered to be a diffuse swelling or cellulitis (5). Some authors have stated that an abscess must be drained surgically and that cellulitis responds to systemic antibiotics (2-4). Others have suggested draining both a cellulitis and fluctuance (5, 6, 47). Frequently, the two conditions coexist as an abscess often begins as cellulitis. Diagnosis may be difficult and may lead to missed abscesses and/or unnecessary invasive procedures. Failure to diagnose correctly leads to inappropriate or delayed therapy which, in turn, can lead to medical complications, extra emergency department or clinic visits, and increased costs (2).

Clinically, there are general differences between a cellulitis and an abscess (fluctuance). A cellulitis is the initial presentation of an infection and is thought to be an acute process. An abscess, while also acute, is often considered the resolution phase of a clinical swelling. The pain described by patients with a cellulitis tends to be more severe and generalized than the localized pain associated with an abscess (6). A cellulitis often presents with swelling, warmth, erythema, and tenderness over the affected area and equates to the descriptive terms “tumor,” “calor,” “rubor”, and/or “dolor (8).” The firmness of the cellulitis can range from doughy to indurated. The firmer the cellulitis and the more rapidly it spreads tends to indicate a more severe infection. The borders of cellulitis are typically large, smooth, ill-defined and do not contain pus. An abscess usually has small and well circumscribed borders and is soft or fluctuant to palpation indicating a pus filled cavity. Patients with systemic infections often have elevated temperatures (6).

It has been suggested in both the medical and dental literature that the use of ultrasonography can aid in the diagnosis of swellings and also in locating the depth
of an abscess to allow a more accurate location for an incision for drainage procedure (3-4, 7-13, 15, 16). While magnetic resonance imaging (MRI) and computed tomography (CT) are valuable diagnostic aids in imaging soft tissue lesions and the spread of infections into fascial spaces; they are not readily available in many dental clinics, are expensive and time-consuming, and expose the patient to large doses of radiation (3). Ultrasonography is quick, widely available, inexpensive, relatively painless, and can be repeated as often as necessary without risk to the patient (7). A review article by Ramirez-Schrempp, et al. (4) stated “Ultrasound is an efficient, noninvasive diagnostic tool which can augment the physician’s clinical examination. Ultrasound has been shown to be superior to clinical judgement alone in determining the presence or the absence of occult abscess formation, ensuring appropriate management, and limiting unnecessary invasive procedures” (4). Squire et al. (2) also showed that ultrasonography is easy to use and after only a 30 minute didactic and hands-on training session, emergency physicians and residents were able to accurately differentiate between an abscess and cellulitis. The didactic portion consisted of images and video clips of abscesses and cellulitis and the hands-on portion allowed the physicians and residents to scan on healthy volunteers (2).

The best probe to use for the assessment of superficial structures, such as abscess or cellulitis, is a high-frequency linear probe (8-12 MHz or higher) (4). In a study by Bassiony and co-authors (7), the echogenecities of the ultrasound were described as hyperechoic (brighter), isoechoic (equal), hypoechoic (darker), anechoic (no internal echoes), or mixed as compared to the adjacent tissues (7).
Normal skin on an ultrasound has a very organized pattern where the dermis and epidermis appear as a single hyperechoic and bright layer relative to the subcutaneous tissue, which is hypoechoic (4). The echogenicities described by Bassiony et al. (7) were the key in their staging of the infections from the acute phase to the complete abscess formation phase. The phases included edematous changes, cellulitis, preabscess stage, and abscess stage. The echogenicities of the tissues in the edematous phase were isoechoic, similar to the normal or uninfected side but with an increase in the fluid content. In cellulitis, the tissues were hyperechoic because of the massive inflammatory infiltration to the infected region. In the preabscess stage, the tissues were mixed (hypoechoic and hyperechoic) indicating that the swelling was at the end of the cellulitis stage and at the beginning of the abscess formation stage. In the abscess stage, the echogenicity of the tissues were anechoic (absent) because of the abscess cavity. This cavity can be solitary or multiple, well defined foci of pus (7). An abscess has also been described as a heterogeneic, anechoic, or hypoechoic mass that contains a variable amount of internal echoes. They are usually spherical in shape with poorly defined borders and movement or “swirling” of the pus may be seen. The cellulitis type of swelling has also been described to show a thickening and diffuse hyperechogenicity commonly referred to as “cobblestoning” (2). The use of color Doppler allows visualization of vascular structures so that they can be avoided during treatment of the swelling (4).

There have been studies and case reports in the medical literature utilizing ultrasound-guided aspiration and irrigation techniques to locate and treat breast,
thyroid, and prostate abscesses over the traditional surgical drainage technique (9-10, 12-13). In a study by Ozseker and co-authors (9), ultrasound was used to detect eleven breast abscesses in ten cases of mastitis and the success of ultrasound guided aspiration and irrigation was determined. They found that ultrasound guided aspiration and irrigation was successful 91% of the time and no further surgical intervention was required. They concluded that this method is more successful in abscesses with a maximum dimension smaller than 3 cm and this should be preferred to surgical drainage which requires general anesthesia and leads to a poorer cosmetic result (9). A study by Leborgne and Leborgne (10) treated 67 patients with sonographically guided aspiration and irrigation of breast abscesses. They injected cephradine, a first generation cephalosporin, into the abscess cavity if it measured more than 25 mm. They had a 96% cure rate with this procedure and believed that the local instillation of the antibiotics was probably beneficial. The three cases in which treatment failed had an abscess of more than 3 cm in diameter (10). However, a study by Christensen et al. stated that neither size nor location of the abscess showed any independent effect on recovery (11). These studies suggest that ultrasound guided aspiration may be preferred to surgical drainage and placement of indwelling catheters in breast abscesses. Two cases reported by Ilyin and co-authors showed that sonographically guided fine needle aspiration was successful in the treatment of thyroid abscesses (12). Also, a case report done by Somuncu et al. concluded that ultrasound guided needle aspiration was successful in the treatment of a patient with a prostate abscess (13). In these cases, antibiotics
were also injected into the abscess cavity (12, 13). In some of the breast and thyroid abscesses, repeat aspirations were needed to cure the patient (10, 12).

There have also been studies in the literature that used ultrasonography to differentiate between fluctuance and cellulitis. A study by Squire et al. (2) sought to determine whether the addition of bedside ultrasonography would increase the diagnostic accuracy for detecting superficial, subcutaneous abscesses. This prospective study included 107 patients who presented with a chief complaint suggestive of cellulitis or abscess. The sensitivity and specificity of the accuracy of clinical examination and ultrasound were reported (2). Sensitivity refers to the “proportion of patients with the target disorder who have a positive test result” (14). Specificity refers to the “proportion of patients without the target disorder who have a negative test result” (14). Positive predictive value is the “proportion of patients with positive test results who have the target disorder” (14). It is defined as the number of true positives divided by the number of true positives plus false positives (14). The negative predictive value is the “proportion of patients with negative test results who do not have the target disorder” (14). It is defined as the number of true negatives divided by the number of true negatives plus false negatives (14). Squire and co-authors found that the sensitivity of clinical examination for abscesses was 86% and the specificity was 70%. The sensitivity of ultrasound examination for abscesses was 98% and the specificity was 88%. Ultrasound and clinical examination disagreed in 18 of the cases. Out of those 18 cases where they disagreed, ultrasound correctly identified 17 (94%). The positive predictive value for clinical exam and ultrasound was 81% and 93%, respectively. The negative
predictive value for clinical exam and ultrasound was 77% and 97%, respectively. The standard criterion for abscess in patients who underwent the drainage procedure was the demonstration of pus. For those patients who did not receive drainage, the resolution of symptoms at a seven-day follow up telephone call was a criterion standard for absence of abscess. Sixty-four patients had incision and drainage (I&D) proven abscess, 17 had negative I&D, and 26 had improved with antibiotics alone (2).

In another study, Tayal et al. (15) evaluated the effect of ultrasound on the management of emergency department patients with clinical cutaneous cellulitis or those without obvious abscess. A total of 126 patients were enrolled in this study. In 56% (71/126) of the cases, ultrasound changed the management of patients with cellulitis. In the group that was believed to have cellulitis and not need drainage, ultrasound changed the management in 48% (39/82) of the cases with 33 patients receiving drainage and 6 requiring further consultation. In the group that was believed to require drainage, ultrasound changed the management in 73% (32/44) of the cases which included 16 in which drainage was eliminated and 16 who required further consultation. They concluded that the ultrasound changed management in about half of the patients who presented to the emergency department with clinical cellulitis. It may guide management by detecting occult abscess, guidance for further consultation or imaging, or the prevention of invasive procedures (15).

There have also been numerous studies that have looked at using ultrasound as an aid in the diagnosis of odontogenic swellings specifically. In a study done in 1987 by Ralf Siegert (16), the use of ultrasound was investigated in the diagnosis of
inflammatory soft tissue swellings of the head and neck region as compared to clinical examination. The final diagnosis was determined on the basis of either surgical intervention or resolution due to nonsurgical treatment. Seventy-nine patients were examined in the study. Five classes were assigned to the ultrasound images. Class I was edema and three patients (4%) were found to fall into this category. It was characterized by enlargement of anatomical structures and slight echoreduction. Class II was the infiltrate category in which 24 patients (30%) were grouped. The images appeared as a diffuse area of increased echointensity and anatomical structures were difficult to delineate. The preabscess category, class III, showed an infiltrate in which there was slight or not well delineated echoreduction. Twelve patients (15%) were placed into this category. Class 4 and 5 were considered to be the abscess category and included 40 patients (51%) who were split into two types. Type I (33%) had echo-free internal structures and type II (18%) were echo-poor. An abscess appeared as a delineated area with posterior enhancement. The sensitivity for diagnosing an abscess clinically and with ultrasound was found to be the same, 93% if the uncertain and questionable (preabscess) category were included. However, ultrasonography did have a higher sensitivity of 82% versus clinical exam of 69% when only the specific diagnosis of abscess was considered. Also, ultrasound was found to be clearly superior at diagnosing infiltrates. The specificity of ultrasound was 86% if preabscesses were included and 71% if not. For clinical examination it was 65% if preabscesses were included versus 43% if not. Therefore, he concluded that ultrasonography should be used to supplement clinical exams in patients with head and neck swellings and
can be used to follow the course of an infection and its response to nonsurgical treatment (16).

More recently, a retrospective study done by Adhikari et al. in 2011 (17) reviewed the records of patients who presented to the emergency department with an odontogenic problem where panoramic x-ray and bedside ultrasound were performed. A total of 19 patients were identified and the purpose of the study was to compare the two techniques in the diagnosis of a dental abscess. In 7 of the 19 patients, no periapical abscess was reported on the panoramic x-ray. In 6 of the 7 cases, ultrasound agreed with the panoramic x-ray. In the one case of disagreement, an incision and drainage was performed and the presence of an abscess was confirmed. A diagnosis of periapical abscess was made by the panoramic x-ray in 12 of the 19 cases and ultrasound agreed with 10 out of the 12. One patient was lost to follow-up but the authors assumed this patient had a dental abscess. They found the sensitivity and specificity of the ultrasound to diagnose a dental abscess were 92% and 100%, respectively (17).

Another study by Bassiony and co-authors (7) investigated ultrasonography as an alternative to magnetic resonance imaging (MRI) in the detection of fascial space spread of odontogenic infections. Forty-two fascial spaces in 16 subjects were examined by ultrasonography and the results were confirmed by MRI and microbiologic tests through aspiration, incision and drainage, or extraction of the teeth. The ultrasound successfully identified 32 (76%) of the 42 spaces and there was 100% agreement with the MRI. The ultrasound detected buccal, submandibular, canine, submasseteric, submental, and infraorbital involvements. It
was unable to detect masticator, parapharyngeal and sublingual space involvements. The ultrasonography proved helpful in staging the infections from edematous changes to cellulitis to abscess formation. The authors concluded that ultrasonography may be useful in detecting and staging the spread of odontogenic infections in superficial fascial spaces, however deep fascial spaces may be difficult to detect (7).

A study by Peleg et al. (3) also showed that ultrasonography is an effective aid in the staging of an infection and in confirming abscess formation in the superficial fascial spaces. They studied 50 patients with acute odontogenic infections of the superficial fascial space. Twenty-four patients had buccal swelling, fifteen had submandibular swelling, four had sublingual swelling, two had periorbital swelling, and five had infraorbital swelling as diagnosed clinically. After clinical and radiographic examination, an ultrasound was used to examine the infected area and an ultrasonically guided needle aspiration was performed. Fluid was identified by ultrasound in 22 of the 50 patients and aspiration of pus was positive in all of these patients. Six of the patients diagnosed as cellulitis had a repeat scan done three day later. Four of the six patients were diagnosed as having an abscess on the third day. They concluded that ultrasonography is a quick, widely available, painless, and inexpensive adjunct. It can be repeated numerous times without risk to the patient to aid in the staging and diagnosing odontogenic infections (3).

Studies have supported that ultrasound may be an effective aid in the diagnosis, management, and treatment of odontogenic infections and therefore it is
important to understand what causes an infection and the routes of spread of an infection. The cause and effect relationship between bacteria and apical periodontitis is supported in the endodontic literature (18-22). WD Miller was the first to suggest, in 1894, that bacteria were the cause of apical periodontitis after isolating bacteria from root canals with apical periodontitis (18). About 70 years later, Kakehasi et.al. (19) conducted a study that examined the response of dental pulps of conventional and germ-free rats exposed to the oral environment. Pulp necrosis and apical periodontitis lesions developed in all of the conventional rats but the pulp remained vital in all of the germ-free rats (19). Sundqvist (20) found bacteria in teeth that became necrotic after trauma only in those with radiographic evidence of apical periodontitis. He also demonstrated that the necrotic tissue and fluid in the root canals cannot induce and maintain apical periodontitis in the absence of bacteria (20). A study by Moller et al. (21) found similar results in that only the pulps of monkey teeth that were devitalized and infected showed signs of apical periodontitis. Those that were devitalized but not infected did not show significant pathologic changes in the periapical tissues. This reinforced that necrotic pulp alone is not able to induce and perpetuate apical periodontitis (21). Stabholz and Sela (22) also made the connection between bacteria and pulp and periapical pathoses. They showed that injecting S. mutans into the canine teeth of cats induced an inflammatory response in the pulp and periapical tissues (22).

Normally, the pulpodentin complex is protected by enamel and cementum from the oral microbiota. When the integrity of these structures is compromised or absent then bacteria have access to the pulpodentin complex via dentinal tubules.
Caries, trauma, fractures or cracks, and dental procedures are some examples of how the outer protective layers can be damaged (5). Nagaoka et al. showed that bacterial invasion of the dentinal tubules occurs more rapidly in teeth with necrotic pulps (23). It is thought that in vital teeth, the fluid and tubular contents delay penetration into tubules (24). Also, other factors such as sclerosis, tertiary dentin, smear layer, and host defense mechanisms help impede bacterial progression in vital pulps (25, 26). Therefore, exposure of the dentin does not result in a significant route for progression of bacteria and infection of the pulp unless the thickness is reduced or permeability increased (5). Even before the pulp is exposed, bacteria can reach the pulp. Local defense cells of a vital pulp can cleanse the bacteria and can eliminate infection (27). However, if the pulp is compromised, even a small number of bacteria can initiate infection (5). The most common cause of pulp exposure is caries and the direct exposure of the pulp is the most obvious route of endodontic infection (5). Bacteria may reach the pulp by other means such as trauma through cracks and iatrogenic procedures. Almost always the exposed pulps will become inflamed, then necrose, and then will become infected. The pulp becomes necrotic in incremental stages. There is a reduction in blood flow as the pulp becomes partially necrotic. “Thus, total pulpal necrosis represents the gradual accumulation of local necrosis” (28). The time of this progression is unpredictable but is usually a slow process as demonstrated by Cvek et. al. when examining the reactions of the pulp to exposure after crown fracture or grinding in monkeys (29). Microorganisms can then progress through the main canal, lateral canals, and accessory foramina to infect the surrounding periradicular tissues (5).
The oral cavity has had more than 700 bacterial species or phylotypes detected and over 400 have been found in infected root canals. Studies have shown that over 50-60% of the microbiota still remains to be cultivated and characterized (5, 30). Most of the literature regarding the microbiota present in odontogenic infections has found it to be polymicrobial with anaerobes being predominant (20, 31-35). A study done by Khemaleelakul and co-authors examined aspirated pus from odontogenic swellings and found strict anerobes were predominant and the most frequently found genera were *Prevotella* and *Streptococci* (31). “Bacteria that are strict anaerobes only grow in an environment with low oxidation reduction potential in an absence of oxygen (28).” Although strict anaerobes outnumber facultative anaerobes, the later are still present in most infections (31, 32). Most facultative anaerobes belong to either the anginous streptococci group or the viridians streptococci group (34). Additional studies have found that the primary anaerobic bacteria isolated are streptococci, fusobacterium and black pigmented anerobes such as *Prevotella* and *Porphyromonas* species (20, 34). Most of the bacteria have been analyzed by culturing techniques, primarily through aspiration of the exudates (34). However, Siqueira and co-authors (36-38) used molecular biological techniques utilizing PCR or DNA-DNA hybridization techniques. This approach showed that the *Treponema* species is also present in the acute dental abscess as well as other unfamiliar species, such as *Filifactor alocis*, *Dialister pneumosintes*, *Pseudoramibacter alactolyticus*, and *Centipede periodontii* (36-38). A recent study by Poeschl and co-authors also confirms that the majority, about 62% of infections, were mixed aerobic-anaerobic infections with streptococci,
staphylococci, prevotella, and peptostreptococcus being predominate (35). A study by Rocas et al. (39) showed that the number of taxa found in the root canal corresponded to the size of the lesion. The larger the lesion, the more taxa found (39).

Recently, there has been evidence to suggest that fungi, archaea, and viruses are also present in endodontic infections. Fungi are eukaryotic microorganisms and the most commonly isolated is the *Candida* species. While most studies show that *Candida* is not common in primary intraradicular infections, one study has reported the occurrence of *C. albicans* in 21% of the samples of primary infections (5, 40). Archaea are a highly diverse group of prokaryotes that are distinct from bacteria. There have been studies that have detected *Methanobrevibacter oralis*-like phylotype in some primarily infected canals (5, 41, 42). Viruses are inanimate particles that are composed of a nucleic acid molecule (DNA or RNA) and a protein coat (5). Human cytomegalovirus (HCMV) and Epstein-Barr virus (EBV) have been isolated from apical periodontitis lesions (43) and are more frequently found in symptomatic apical periodontitis lesions (44), large lesions (43), and lesions from HIV positive patients (45).

When bacteria progress from an infected tooth into the periradicular tissues and the immune system is unable to suppress the invasion, a patient will eventually exhibit signs and symptoms of cellulitis, abscess, or both (5). The infection generally progresses through the area of thinnest bone and then out into the tissue (6). “Fascial spaces are potential anatomic areas that exist between the fascia and underlying organs and other tissues (5).” These spaces are formed or invaded by
purulent exudates and do not exist in healthy patients. Swellings may be localized
to the vestibule or spread into facial spaces and this depends on the relationship of
the infected tooth apices to the muscular attachments (5, 6). The spaces involved in
odontogenic infections can be classified as primary maxillary spaces, primary
mandibular spaces, and secondary fascial spaces which comprises the cervical
spaces (6).

The primary maxillary spaces include the buccal vestibular, canine, base of
the upper lip, buccal, palatal, infratemporal, and periorbital spaces. The maxillary
buccal vestibular space is involved when a posterior maxillary tooth is the source of
infection. It is the area between the buccal cortical plate, overlying mucosa, and the
buccinator muscle which is the most superior extent. The apex of the involved
tooth lies below the level of attachment of the buccinator muscle (5). The canine
(or infraorbital) space is located between the levator anguli oris muscle inferiorly
and the levator labii superioris muscle superiorly. The primary tooth involved is the
maxillary canine; however, the maxillary first premolar may also be responsible (5,
6). Obliteration of the nasolabial fold is often seen when this space is involved (6).
The maxillary central incisor is primarily responsible for swellings at the base of the
upper lip. The apex of the tooth lies above the orbicularis oris muscle attachment
(5). The boundaries of the buccal space are the buccinator muscle on the medial
aspect and the skin of the face on the lateral aspect. When the infection from
maxillary posterior teeth erodes through the bone superior to the buccinator muscle
attachment then the buccal space is involved (5, 6). A palatal space swelling will
arise when an infection from any maxillary tooth erodes through the palatal bone
because the apex is in close proximity (5). Posterior to the maxilla is the infratemporal space which is between the lateral plate of the pterygoid process of the sphenoid bone medially, the base of the skull superiorly, and is continuous with the deep temporal space laterally. Although involvement of this space is rare, when it does occur it is usually attributed to infection by a maxillary third molar (6). The space that is located deep to the orbicularis oculi muscle is the periorbital space. This space is usually involved by spread from the canine or buccal spaces (5). Periorbital or orbital cellulitis is rare, but is a serious infection which requires aggressive medical and surgical intervention (6). Another serious complication of an odontogenic infection may result via the hematogenous route and is referred to as cavernous sinus thrombosis (5, 6). Cavernous sinus thrombosis is a “life-threatening infection in which a thrombus formed in the cavernous sinus breaks free, resulting in blockage of an artery or the spread of infection (5).” It requires immediate medical attention and aggressive medical and surgical intervention due to its high mortality rate (6).

The primary mandibular spaces include the body of the mandible, buccal vestibular, mental, submental, buccal, sublingual, and submandibular spaces. Any mandibular tooth can be the source of infection of the body of the mandible or the mandibular buccal vestibule. The body of the mandible space lies between the buccal or lingual cortical plate and the periosteum and can occur as a result of a postsurgical infection. The buccal vestibular space is the space that lies between the buccal cortical plate, the overlying alveolar mucosa, and the buccinator muscle in the posterior and the mentalis muscle in the anterior. The exudate erodes through
the buccal cortical plate and the apex or apices of the involved tooth lie superior to
the buccinator muscle attachment. The mental space is involved when the apex of
an anterior tooth lies below the attachment of the mentalis muscle and the exudates
erode the buccal cortical plate. The space is potentially bilateral and is bordered
superiorly by the mentalis muscle and inferiorly by the platysma muscle. When the
infection of an anterior tooth erodes through the lingual cortical plate and the apex
of the tooth is below the level of attachment of the mylohyoid muscle, then the
submental space is involved. The mylohyoid muscle borders it superiorly and the
platysma muscle borders it inferiorly (5). The buccal space can also become
infected from a mandibular tooth in a way similar to its involvement from a
maxillary tooth. Maxillary teeth are more commonly the teeth that cause
involvement of the buccal space but it has been seen with mandibular teeth as well
(6). The borders of the sublingual space are the oral mucosa of the floor superiorly,
the mylohyoid muscle inferiorly, and the lingual borders of the mandible laterally.
The posterior aspect of the space is open and therefore it freely communicates with
the submandibular space. The sublingual space becomes infected when a
mandibular tooth infection erodes through the cortical plate and the apex or apices
of the involved tooth lie above the mylohyoid muscle attachment. The
submandibular space is located between the mylohyoid muscle superiorly and the
platysma inferiorly and it communicates with the secondary fascial spaces
posteriorly. This space becomes involved when a mandibular posterior tooth is
infected and the apices of the tooth lie below the mylohyoid muscle attachment.
Ludwig’s angina occurs when bilateral submandibular, sublingual, and submental
spaces are involved with an infection. This is a life-threatening infection that rapidly and commonly spreads to the secondary fascial spaces and results in airway obstruction (5, 6). Unlike cavernous sinus thrombosis, this life-threatening infection is most commonly caused by an odontogenic infection and streptococci are the main bacteria involved. Aggressive medical and surgical management is needed (6).

When primary odontogenic infections are not properly treated, the infection can spread posteriorly to involve the secondary and cervical fascial spaces. Once these spaces become involved, the infection becomes more difficult to treat and more complications and morbidity arise. The secondary spaces include; the masseteric, pterygomandibular, and superficial and deep temporal spaces. The masseteric space (also called submasseteric) is the area between the lateral aspect of the ramus of the mandible and the medial aspect of the masseter muscle. This space is usually involved by spread of infection from the buccal space or infection from a maxillary third molar in which the apices of the tooth lie within or in close proximity to the space (5, 6). The patient experiences swelling over the ramus and angle of the jaw and usually exhibits trismus due to inflammation of the masseter muscle (6). The pterygomandibular space is between the medial surface of the mandible and the lateral surface of the medial pterygoid muscle. This space can become infected with spread from the submandibular and sublingual spaces, an infection of a mandibular second or third molar, or needle tract infection from a mandibular block (5, 6). Visible swelling may not be seen but significant trismus is usually involved and is a good sign that this space is infected (6). The space that
lies superior and posterior to the masseteric and pterygomandibular spaces is the
temporal space and it is divided into two portions by the temporalis muscle; the
superficial and deep temporal spaces. The superficial space extends to the temporal
fascia, whereas the deep space is continuous with the infratemporal space.
Involvement of these spaces is rare and indicates a severe infection. The patient
will exhibit swelling in the temporal area above the zygomatic arch and posterior to
the lateral orbital rim (6).

The cervical spaces include: the lateral pharyngeal, retropharyngeal,
prevertebral, pretracheal, and danger spaces. The parapharyngeal spaces include
the lateral pharyngeal and retropharyngeal spaces. The lateral pharyngeal space lies
between the medial pterygoid muscle laterally and the superior constrictor muscle
medially, the base of the skull superiorly and the hyoid bone inferiorly, the
pterygomandibular raphe anteriorly and the prevertebral fascia or carotid space
posteriorly (5, 6). When this space is involved, the infection is severe and is
progressing rapidly. Severe trismus is involved and swelling is seen on the lateral
neck below the angle of the mandible. The patients are usually very sick with a
high temperature and have difficulty swallowing (6). Other complications may also
arise and include: “thrombosis of the internal jugular vein, erosion of the carotid
artery or its branches, and interference with cranial nerves IX through XII (6).”
Further complications can arise if infection from this space progresses to the
retropharyngeal space. The retropharyngeal space has as its borders the superior
constrictor muscles anteriorly, the prevertebral fascia posteriorly, and the
retroesophogeal space inferiorly which extends into the posterior compartment of
the mediastinum (5, 6). The major concern of infection of this space is that it can extend inferiorly into the mediastinum very rapidly and infection of the mediastinum is a serious complication (6). Involvement of the parapharyngeal spaces is usually due to spread of infection from other fascial spaces or directly from a peritonsillar abscess. The retropharyngeal space and the retroesophageal spaces make up the retrovisceral space (5). The space surrounding the vertebral column is the prevertebral space. It extends from the C1 vertebra to the coccyx and infection of this space can extend to the diaphragm and can involve the thorax and mediastinum along the way (5, 6). The potential space that surrounds the trachea is the pretreacheal space. It extends from the thyroid cartilage to the anterior compartment of the mediastinum and to the level of the aortic arch. Odontogenic infections do not spread directly to this space due to its location, but it can become secondarily infected. The potential space located between the alar and prevertebral space is the danger space. This space is considered an actual anatomic space because it is comprised of loose connective tissue. It extends from the base of the skull to the posterior compartment of the mediastinum to the diaphragm (5). Infections of these spaces require aggressive medical and surgical attention (5, 6).

As stated previously, the management and treatment of swellings may depend upon the stage of infection. In all cases, the odontogenic source of infection should be eliminated by either root canal therapy or tooth extraction. Antibiotics are recommended only in cases of progressive or persistent infections with systemic signs and symptoms such as fever, malaise, cellulitis, unexplained trismus (5). Whether or not an abscess or cellulitis should be drained is somewhat controversial.
Some authors believe that an abscess or localized fluctuant swelling should be treated with an incision and drainage and cellulitis should be managed with antibiotic therapy (2-4). The “Pathways of the Pulp” textbook states an incision and drainage is indicated for any infection marked by cellulitis whether it is indurant or fluctuant (5). The Summer 2006 Endodontic Colleagues for Excellence pamphlet agrees that an incision for drainage and antibiotics should be administered for cellulitis or swellings increasing in size (47). It is argued that it is important to provide a pathway of drainage for bacteria and inflammatory mediators to prevent further spread of the abscess/cellulitis. The I&D will allow decompression of the increased tissue pressure associated with edema (5). With this reduction in tissue tension, local blood supply and the delivery of host defenses to the area are improved (6). Improved circulation to the area is thought to improve the delivery of the antibiotic to the site (47). For effective drainage, an incision should be made through the periosteum in the most dependent site of the swelling and then blunt dissection using a curved hemostat or periosteal elevator should be performed for drainage of pockets of inflammatory exudates. However, clinically, it is sometimes difficult to tell where the most dependent site is or what stage the infection is in. A penrose drain or rubber dam may be placed to maintain an open pathway for drainage, but this too is controversial (5). It is thought that the introduction of oxygen to the area may aid in eliminating anaerobic bacteria. As stated previously, strict anaerobes grow only in an oxygen free environment and lack the superoxide dismutase and catalase enzymes (28). Singer and co-authors found that incision and drainage of an abscess in a medical emergency department was the second most
painful procedure performed after nasogastric intubation (46). Therefore, it is important to review the literature and investigate if unnecessary therapy can be eliminated with the use of an ultrasound.

As listed in the Summer 2006 Endodontic Colleagues for Excellence article, adjunctive antibiotics should be administered if a patient has one or a combination of the following: “fever > 100 °F, malaise, lymphadenopathy, trismus, increased swelling, cellulitis, osteomyelitis, and/or persistent infection” (47). The conditions not requiring antibiotics are; “pain without signs and symptoms of infection (symptomatic irreversible pulpitis and symptomatic acute periodontitis), teeth with necrotic pulps and a radiolucency, teeth with a sinus tract (chronic periradicular abscess), and localized fluctuant swellings.” The drug of choice is penicillin VK due to its effectiveness against anaerobic and facultative organisms that are associated with endodontic infections (47). However, more recently, the combination of amoxicillin with clavulanate (Augmentin) has been shown to be the most effective (31, 35, 47, 48). Clindamycin is the recommended choice in patients with an allergy to penicillin, however, it has recently been suggested that endodontic organisms are showing increasing resistance to the drug (35, 47).

Matthews et al. (49) conducted a systematic review of the literature and meta-analysis on the effectiveness of interventions used in the management of acute apical abscess in the permanent dentition. They concluded that the abscess should be drained through debridement or incision and drainage and that antibiotics are of no additional benefit. Only in the event of systemic complications (fever,
lymphadenopathy, or cellulitis) or an immunocompromised patient should antibiotics be prescribed in addition to the incision and drainage procedure (49).

A prospective, randomized, single-blind study done by O’Malley and co-authors (50) examined whether the routine packing of simple cutaneous abscesses with non-iodophor-impregnated gauze after incision and drainage confers any benefit over I&D alone. They had forty-eight subjects who were randomly assigned into either the packing or no packing group after incision and drainage of the abscess. They found no significant differences in initial pain scores between the two groups and also no significant differences in the need for a second intervention at the 48 hour follow-up. Patients in the packing group reported higher pain scores immediately postoperatively and at 48 hours postoperatively, as well as greater pain medication use. They concluded that not packing simple cutaneous abscesses did not result in any increased morbidity and that patients reported less pain and the use of fewer pain medications than the packed group (50).

The blind surgical incision and drainage of abscesses based on clinical exam alone may result in excessive tissue trauma, unnecessarily extensive incisions, excess time, pain and failure to locate and evacuate the abscess cavity (51). Ultrasound has been reported to be a useful tool in the location and delineation of size of an abscess (3, 4, 7-13, 15, 16). Two studies have been done using ultrasound as a guide to draining odontogenic infections. The first study by Yusa et al. (52) used an ultrasound guided surgical drainage of face and neck abscesses. They visualized the abscess with grey-scale ultrasound then used color Doppler to detect vessels close to the abscess and to examine the anatomical locations of the
abscess and surrounding blood vessels. Eight subjects were included. An aspiration was performed under local anesthesia to the depth that was predetermined by the ultrasound. They reported that the ultrasound provided easy detection and accurate, reliable penetration of the abscesses that were difficult to locate by physical exam. Patients did not complain of severe pain and there were no complications during or after aspiration. For all the patients, the ultrasound guided drainage of the abscess was conclusive and no additional or subsequent drainage was needed (52). In a study by Fouad Al-Belasy (53), ultrasound guided drainage of patients with submasseteric space abscesses of odontogenic origin was studied. The surgical approach for drainage of this space is very difficult and requires general anesthesia. Eleven patients were included in this study. They were examined with the ultrasound and their swellings were drained with ultrasound guidance using a 16-gauge intravenous catheter. The ultrasound guided drainage was repeated at 24 hours, and 24 hours later the patient’s infection course was monitored. If the infection was not resolving then the patients would receive an extraoral incision and drainage. They found that 73% of the patients had resolution of their infection after the ultrasound guided drainage. This confirms the therapeutic value of ultrasound in the management of infections (53).

The use of ultrasonography to aid in the diagnosis of fluctuant swellings (abscesses) from cellulitis and in the management of such swellings may prove to be useful. The purpose of this prospective investigation was to compare the accuracy of clinical examination plus ultrasonography versus clinical examination alone in the diagnosis of cellulitis and fluctuant swellings in symptomatic patients
with a diagnosis of pulpal necrosis, acute apical abscess or cellulitis, and clinical swelling.
Eighty-two adult emergency patients who presented to The Ohio State College of Dentistry participated in this study. The patients were determined to be in good health by oral questioning and their written health history form, and were categorized as ASA Class I or II. Patients were excluded if they were younger than 18, had allergies to local anesthetics, were pregnant, had a history of significant medical conditions (ASA III or greater), or were unable to give informed consent. The study was approved by The Ohio State University Human Subjects Review Committee. The subjects provided written informed consent and authorization to use personal health information in research. A Corah’s Dental Anxiety Scale Questionnaire was then completed by the subjects (54-56). This questionnaire asked four dentally related situation questions to help rate the anxiety level of the subjects. The scores ranged from 4 to 20 (56).

To qualify for this study, patients had a symptomatic necrotic tooth with an acute apical abscess or cellulitis and clinical swelling at the time of treatment. Each tooth tested negative to an electric pulp tester (Analytic Technology Corp., Redmond, WA) and negative to Endo-Ice (Hygenic Corp., Akron, OH) which confirmed the swellings were of odontogenic origin. Patients were excluded if a
draining sinus tract was present. The patient’s temperature was taken orally with either the Tempa Dot™ thermometer (3M St. Paul, MN) or the Sure Temp Plus (Welch Allyn, San Diego, CA). They were placed under the patient’s tongue and the temperature was recorded.

The patients were asked to complete a Heft-Parker visual analog scale (VAS) to rate their initial pain. The VAS is 170 mm long and was divided into four categories. No pain corresponded to 0 mm. Mild pain was defined as greater than 0 mm and less than or equal to 54 mm and included the descriptors of “faint”, “weak”, and “mild” pain. Moderate pain was defined as greater than 54 mm and less than 114 mm. Severe pain was defined as equal to or greater than 114 mm and included the descriptors of “strong”, “intense”, and “maximum” pain possible.

A clinical examination was performed by the primary investigator by palpating the swelling to determine if it was considered a cellulitis or fluctuance. A diagnosis of cellulitis was made if the swelling was firm, warm or hot, and no observable fluid movement (purulence) was detected. A fluctuant swelling was diagnosed if there was believed to be fluid movement under the tissue, indicating that pus was present. The tentative clinical diagnosis was recorded.

The swelling was then evaluated using a portable Acuson p50 (Siemens, Munich, Germany) ultrasound unit that produces high resolution images (57). According to the manufacturer, it provides excellent tissue differentiation, high temporal and spatial resolution, and color Doppler imaging (58). A radiology technician, who trains radiologists to use the machine, was available to train the
operator and to determine the proper settings to capture the best images to view fluctuance and/or cellulitis in the oral environment. Each patient’s swelling was viewed in 2-dimensional (2D), power Doppler, and color Doppler modes. The 2D mode uses 256 digital beam-forming channels to display two-dimensional images of the anatomy in a gray color scheme. The power Doppler images show blood flow by displaying the density of the red blood cells. In this mode, flow displays are in shades of the same color where bright hues represent large amplitude signals and dim hues represent weak signals. It is more sensitive than color Doppler and therefore displays more real signals. It is also more sensitive to low-flow and is often used to evaluate perfusion and vessel patency. Color Doppler mode is useful in detecting the mean velocity of blood flow within an assigned region of interest, such as a vessel. It assigns color-coded information and shades of red represent higher frequency flow towards the transducer and blue represents lower frequency flow away from the transducer (57). This information was collected to aid in identifying vessels and blood flow near and/or within the swelling. Images in all three modes were captured and saved. Loop images or videos were captured if swirling of pus was seen.

The best probe to use for the assessment of superficial structures, such as an abscess or cellulitis, is a high-frequency linear probe (8-12 MHz or higher) (4). The transducer chosen for this study was the 12L5 linear wideband array transducer. It has a maximum depth of 80 mm (8 cm) and has a frequency range of 4.8-12.0 MHz. It is used for peripheral vascular and cerebrovascular types of exams and is also
applicable for breast and thyroid imaging (57, 58). The depth of a mass in the breast and thyroid are similar to the depth of a swelling in the oral environment.

The Acuson P50 works with Microsoft Windows (Microsoft®, Redmond, WA) standard software and comes installed with customized exams for viewing different types of anatomy; such as cardiac, breast, and thyroid. Along with a trained radiology technician sent by Siemens, a custom exam was developed to view soft tissue swellings of the head and neck and was based closely on the preset exams of the thyroid and breast. The size of the patient was set to medium and only changed if a very small or large patient presented for treatment. The smallest size sets the highest transmission frequency, the medium size sets a mid-range frequency, and the largest size sets the lowest frequency for the best penetration. The frequency was set to very high (VH) and is only an available option when using the 12L5 transducer. The breast and thyroid exams use the high frequency as compared to the carotid exam which uses a medium frequency. The exact frequencies depend on the type of transducer that is connected. The maximum depth was set to 4 cm as it is in the breast and thyroid exams. Increasing the depth allows the operator to view larger or deeper structures and decreasing the depth enlarges the display of structures near the surface of the skin. The focus increases the resolution of a specific area to optimize the image. The primary focus depth was set at 2 cm. The number of focus points was set at 3. The focus and distribution method are the same as the breast and thyroid presets. The frame rate decreases by increasing the number of focal zones. The frequency, depth, and focus were not changed between patients. The gain was adjusted case by case to brighten
or darken the image. Adjusting time gain compensation corrects for attenuation by adjusting the amplification of returning signals and therefore, equalizes the brightness of echoes. The image format was set to linear as opposed to trapezoidal. The value of the smoothing field was set at the letter D. It ranges from A to E and the amount of smoothness increases as the higher letters are selected. The selection of smoothness is subjective and although a higher level may be selected, a visibly smoother image is not always seen. Persistence values range from 0-7 (0-100%) and for this study it was set at 3. When the rate is high, the image appears smoother and less speckled. However, a high persistence also increases the possibility of a blurred image if the tissue is moving when freezing of the image is done. The image map was set at C as the range is from A to H. It allows the operator to choose how grayscale is distributed and each map emphasizes certain regions of the signal amplitude range. The signal compression can be adjusted case by case and affects the contrast of the image. The noise rejection also can be adjusted to control the rejection of low-level returned signals. The image background appears darker as the rejection is increased and vice versa. When using the power Doppler and color Doppler modes additional controls are needed. The pulse repetition frequency (PRF), which defines the velocity range of display, was set at 1500 for the power Doppler and 250 for the color Doppler modes. This value depends on the specific transducer used and the region of interest. It should be set high enough to prevent aliasing (or the images being indistinguishable) or and low enough to provide adequate detection of low flow and may be varied during an exam based on the speed of blood flow (57).
Following a clinical examination, the 12L5 ultrasonic transducer was placed over the swelling and a diagnosis of cellulitis or fluctuance was made. A water-based Aquasonic® gel (Parker Lab Inc., Fairfield, NJ) was used as the medium between the transducer and the patient’s skin to eliminate air bubbles. Slight pressure was applied and patients were asked to report where the swelling was most tender. Cellulitis showed a thickening and diffuse hyperechogenicity commonly referred to as “cobblestoning” (2) (Figures 6 & 7). The fluctuant swelling showed a heterogeneous, anechoic, or hypoechogenic mass containing variable amounts of internal echoes. Abscesses are generally spherical in shape with poorly defined borders. Compression of the mass with the transducer may demonstrate movement or “swirling” of the pus (2) (Figures 8 & 9). The investigator who performed ultrasonography was trained by a radiology technician sent by the company in the use of the ultrasound unit and interpretation of the results. Also, a trained radiologist worked with the investigator on patients to train on differentiating between cellulitis and fluctuance. The depth, height, and width of an anechoic area, indicating fluctuance, was measured if observed on ultrasonography using the measuring device available with the system’s program. Images were also taken in the power Doppler and color Doppler modes (Figures 10 & 11, respectively). The tentative diagnosis was recorded. The primary investigator reviewed the images and made a diagnosis in a blind randomized setting, without the patient present. The images were randomized by another operator and then decoded by that same operator. At least one week later, the images were re-randomized by the other
operator and the investigator reviewed them and recorded a diagnosis. This was
to determine investigator reliability. An expert radiologist also viewed the
images and recorded a diagnosis without the patient present to compare accuracy
with the primary investigator. At least one week later, the images were re-
randomized and the expert reviewed and recorded a diagnosis. This was to
determine the expert’s reliability.

An incision and drainage procedure was performed by another
investigator after the administration of local anesthesia while the primary
investigator was present. The incision was made through the most dependent
site of the swelling using a scalpel. A blunt dissection using a curved hemostat
was then performed to the depth of the swelling. The presence of purulence or
no purulence was recorded by both operators.

The success of the clinical examination plus ultrasound versus clinical
examination alone was based on whether purulence was detected and confirmed
during incision and drainage. The McNemar test was used to evaluate the
percentage correct diagnosis between the two diagnostic techniques. With a
non-directional alpha risk of 0.05 and assuming a success rate of 50% (chance),
a sample size of 40 subjects per group was required to achieve a power of 0.82
for a ±30 percentage point difference in achieving a correct diagnosis.

Sensitivity, specificity, positive predictive value, negative predictive value, and
accuracy along with their 95% percent confidence intervals were calculated.
The reliability of the operator and expert were calculated using the reliability
coefficient, kappa.
CHAPTER 3

RESULTS

Eighty-two adult patients participated in this study; thirty-six were female (43.9%) and forty-six were male (56.1%) (Table 2). Table 1 shows that the mean age was 37.2 +/- 13.6 years old. The mean initial pain rating, using the Heft-Parker visual analog scale, was 108.9 +/- 40.5 mm, which is at the high end of the moderate scale. When a central area of pus was believed to be seen on the ultrasound, measurements were recorded. Measurements were not recorded for all patients. The depth was recorded from the top of the screen (which was the skin surface) to the central hypoechoic or anechoic area. Fifty-two swellings were measured for depth and the mean was 12.8 +/- 3.4 mm. When a purulence pocket was suspected, the width and height of the pocket were recorded. Forty-seven patients were measured and the mean width was 20.1 +/- 6.6 mm and the mean height was 6.5 +/- 3.2 mm. Width referred to the anterior-posterior extent of the swelling. Height referred to the surface of the skin to bone extent of the swelling.

Table 2 lists preoperative variables for all subjects. Swellings were seen in the maxilla in thirty-eight patients (46.3%) and the mandible in forty-four patients (53.7%). Thirty-eight patients (46.3%) had left sided swelling and forty-four patients (53.7%) had right sided swelling. Thirty subjects (37%) reported taking
antibiotics. Overall, 14 teeth (17.1%) associated with the swellings were maxillary anterior, 24 (29.3%) were maxillary posterior, 3 (3.7%) were mandibular anterior, and 41 (50%) were mandibular posterior.

Table 3 shows the tooth type and gender grouped by cellulitis and fluctuance. For the cellulitis group, 5 teeth (16.7%) were maxillary anterior, 7 (23.3%) were maxillary posterior, 0 were mandibular anterior, and 18 (60%) were mandibular posterior. For the fluctuant group, 9 teeth (17.3%) were maxillary anterior, 17 (32.7%) were maxillary posterior, 3 (5.8%) were anterior mandibular, and 23 (44.2%) were mandibular posterior. The cellulitis group had 14 females (46.7%) and 16 males (53.3%) and the fluctuant group had 22 females (42.3%) and 30 males (57.7%).

Table 4 demonstrates the number of cellulitis versus fluctuant type swellings recorded with clinical exam alone, clinical exam plus ultrasound, findings after incision for drainage, ultrasound diagnosis alone, and the expert ultrasound diagnosis alone. With clinical exam alone, a diagnosis of cellulitis was made 14 out of 82 times (17.1%) and a diagnosis of fluctuance was made 68 out of 82 times (82.9%). With clinical exam plus ultrasound, cellulitis was diagnosed 19 out of 82 times (23.2%) and fluctuance was diagnosed 63 out of 82 times (76.8%). The number of swellings determined to be cellulitis or fluctuant, found after incision for drainage, were 30 (36.6%) and 52 (63.4%), respectively (Table 4). These findings after incision for drainage were used as the standard. The operator using the ultrasound alone made the diagnosis of cellulitis 22 out of 81 times (27.2%) and a diagnosis of fluctuance 59 out of 81 times (72.8%). The expert using the ultrasound
alone diagnosed cellulitis 29 of 81 times (35.8%) and fluctuance 52 of 81 times (64.2%). The total number for the ultrasound readings alone was 81 which is one short of that with clinical exam and clinical exam plus ultrasonography. This is because one of the patient’s images was not retrievable from the computer for the latter viewings without the patient present.

Clinical exam alone versus clinical exam plus ultrasonography for diagnosis is demonstrated in Table 5. With clinical exam alone a correct diagnosis was made 56 of 82 times (68.3%). With clinical exam plus ultrasonography a correct diagnosis was made 57 of 82 times (69.5%). Only one more correct diagnosis was attained by adding ultrasonography and this was not statistically significant (p > 0.5).

Cellulitis was used as the positive variable, meaning the clinical standard of what we were attempting to detect on ultrasound, and fluctuance was the negative variable. Table 6 shows the statistical analysis of the data. Clinical exam detected true positives (cellulitis) 9 out of 30 times (30%). Clinical exam plus ultrasonography detected true positives (cellulitis) 12 out of 30 times (40%). True positive (cellulitis) detection with the use of the ultrasound alone by the operator and ultrasound alone by the expert were 10 (33%) and 16 out of 30 (53.3%), respectively. Clinical exam alone detected true negatives (not cellulitis, therefore fluctuance) 47 out of 52 times (90.4%) and clinical exam plus ultrasonography detected true negatives 45 out of 52 (86.5%). Detection of true negatives with ultrasound alone by the operator and ultrasound alone by the expert were 40 (77%) and 39 out of 52 (75%), respectively. False positives (meaning a diagnosis of
cellulitis was made when it was found to be fluctuance upon incision for drainage) were detected by clinical exam, clinical exam plus ultrasonography, ultrasound alone by operator, and ultrasound alone by expert, 6.1%, 8.5%, 14.8%, and 16%, respectively. False negatives (meaning a diagnosis of fluctuance was made when it was found to be cellulitis upon incision for drainage) were detected by clinical exam, clinical exam plus ultrasonography, ultrasound alone by operator, and ultrasound alone by expert, 25.6%, 22%, 23.5%, and 16% of the time, respectively.

The sensitivity (the ability to detect cellulitis when it was cellulitis) of the clinical exam alone was 30% and for clinical exam plus ultrasonography was 40% (Table 6 and Figure 1). When using ultrasound alone by operator and expert, sensitivity was 34.5% and 55.2%, respectively (Table 6 and Figure 1). The specificity (the ability to not detect cellulitis when cellulitis is not present, therefore fluctuance) was 90.4% for the clinical exam alone and 86.5% for the clinical exam plus ultrasonography (Table 6 and Figure 2). The specificity for ultrasound alone by the operator and expert were 76.9% and 75%, respectively (Table 6 and Figure 2). The positive predictive value is the “proportion of patients with positive test results who have the target disorder” and the negative predictive value is the “proportion of patients with negative test results who do not have the target disorder” (Sackett). Table 6 and Figure 3 show the positive predictive values as 64.3% for the clinical exam alone, 63.2% for the clinical exam plus ultrasonography, 45.5% for ultrasound diagnosis alone by operator, and 55.2% for ultrasound diagnosis alone by expert. The negative predictive values are 69.1% for the clinical exam alone, 71.4% for the clinical exam plus ultrasonography, 67.8% for ultrasound diagnosis
alone by operator, and 75% for ultrasound diagnosis alone by expert (Table 6 and Figure 4). The values of accuracy are 68.3% for the clinical exam alone, 69.5% for the clinical exam plus ultrasonography, 61.7% for ultrasound diagnosis alone by operator, and 67.9% for ultrasound diagnosis alone by expert (Table 6 and Figure 5). All data points are within the confines of the 95% confidence limits.

Table 7 shows the reliability of the operator and the expert. Both operator and expert read the images separately in a randomized order two times to assess reliability amongst themselves. A kappa from 0 to less than 0.4 is considered marginal reproducibility. A kappa between 0.4 and 0.75 is considered good reproducibility and a kappa greater than 0.75 is considered excellent reproducibility. A kappa of 1 means 100% reliability (59). The operator had a reliability coefficient (K) of 0.81 and p-value of 0.00. The expert had a reliability coefficient (K) of 0.32 and p-value of .0012.
CHAPTER 4

DISCUSSION

The purpose of this study was to compare the accuracy of clinical examination plus ultrasonography versus clinical examination alone in the diagnosis of cellulitis and fluctuant swellings in symptomatic patients with a diagnosis of pulpal necrosis, acute apical abscess or cellulitis, and clinical swelling.

It is believed that identifying the correct diagnosis of an odontogenic swelling is important to render the appropriate treatment. However, it has been suggested that the two conditions (fluctuance and cellulitis) may coexist making diagnosis difficult which in turn may lead to missed abscesses and/or unnecessary invasive procedures (2). Failure to diagnose correctly may lead to inappropriate or delayed therapy which in turn can lead to medical complications, extra emergency department or clinic visits, and increased costs (2). For this study, cellulitis was recorded as the positive response, as seen on ultrasound, due to this condition being more severe in nature than fluctuance, which was the negative response. This is important to understand when the statistical analysis of the investigation is discussed.

The clinical descriptors of cellulitis and fluctuance are important to understand as well as the different opinions on treatment. This will help clarify
as to why it is important to make a distinction between the two conditions prior to treatment. “Swellings may be localized or diffuse, fluctuant or firm” (5). A fluctuant swelling is localized and characterized by the sensation on palpation that there is fluid movement under the tissue, indicating pus is present. A swelling that spreads through adjacent soft tissue and dissects tissue spaces along fascial planes is considered to be a diffuse swelling or cellulitis (5). Typically, the pain associated with a cellulitis is described by patients as more severe and generalized than the localized pain associated with an abscess (6). In the present study, it was found that 75 out of 82 (91.5%) patients reported moderate-to-severe pain initially. In the fluctuant group, 28 out of the 52 (53.9%) patients reported moderate pain and 21 out of 52 (40.4%) reported severe pain. In the cellulitis group, 11 out of the 30 (36.7%) patients reported moderate pain and 15 out of 30 (50%) reported severe pain. While the fluctuance group did have slightly more patients rate their pain as moderate and the cellulitis group had slightly more patients rate their pain as severe, the numbers were close. This suggests that the majority of swellings are painful and pain may not be a useful indicator as to differentiating the type of swelling present.

Other descriptors of cellulitis include warmth, erythema, and tenderness over the affected area and are often described as “tumor,” “calor,” “rubor”, and/or “dolor (8).” The firmness of the cellulitis can range from doughy to indurated. The firmer the cellulitis and the more rapidly it spreads indicates a more severe infection. The borders of cellulitis are typically large, smooth, and
ill-defined and cellulitis does not contain pus. An abscess, on the other hand, usually has small and well circumscribed borders and is soft or fluctuant to palpation indicating a pus filled cavity. A cellulitis is the initial presentation of an infection and is thought to be acute process. Often cellulitis is seen with systemic involvement (6). Some authors believe that an abscess or localized fluctuant swelling should be treated with an incision and drainage and cellulitis should be managed with antibiotic therapy (2-4). However, this is still somewhat controversial. The “Pathways of the Pulp” textbook recommends an incision and drainage for any infection marked by cellulitis whether it is indurant or fluctuant (5). The summer 2006 Endodontic Colleagues for Excellence pamphlet agrees that an incision for drainage and antibiotics should be administered for cellulitis or swellings increasing in size (47). It is argued that it is important to provide a pathway of drainage for bacteria and inflammatory mediators to prevent further spread of the abscess/cellulitis. The incision for drainage will allow decompression of the increased tissue pressure associated with edema (5). With this reduction in tissue tension, it is believed that the local blood supply and the delivery of host defenses to the area will be improved (6). It is believed that the introduction of oxygen to the area may aid in eliminating anaerobic bacteria since strict anaerobes only grow in an oxygen-free environment and lack the superoxide dismutase and catalase enzymes (28). Also, improved circulation to the area is thought to improve the delivery of the antibiotic to the area (47). As stated previously, the two conditions frequently coexist as an abscess often begins as cellulitis and this may further complicate
the clinical situation and decision on treatment. More evidence based research is needed on the appropriate treatment of odontogenic swellings.

The Acuson p50 (Siemens, Munich, Germany) was the ultrasound chosen for this study because it produces high resolution images, excellent tissue differentiation, high temporal and spatial resolution, and color Doppler imaging \((57, 58)\). The machine is lightweight and portable which is an advantage in dentistry. This ultrasound was chosen over the newer handheld machines because it offers color Doppler imaging of vascular structures. The color Doppler feature is not available on the handheld machines. The best probe to use for the assessment of superficial structures, such as abscess or cellulitis, is a high-frequency linear probe \((8-12 \text{ MHz or higher})\) \((4)\). The transducer chosen for this study was the 12L5 linear wideband array transducer. It has a maximum depth of 80 mm and has a frequency range of 4.8-12.0 MHz. It is used for peripheral vascular and cerebrovascular types of exams and is also applicable for breast and thyroid imaging \((57, 58)\). The depth of a mass in the breast and thyroid are similar to the depth of a swelling in the oral environment. The patients were examined with ultrasound by placing a water based gel as the medium between the transducer and the patient’s skin to eliminate air bubbles. Also, pressure was applied and patients were asked to indicate the most tender area of the swelling to help aid in viewing the central area of the swelling. The cost of a new p50 ultrasound unit is about $20,000 – 30,000. The cost of the machine versus the benefit of adding it to clinical examination will be discussed later.
A review of the literature identified two studies in which the authors classified the type of swelling on ultrasound using a variety of descriptive terms and sample ultrasound images. These studies served as a guide to help the investigator make an accurate diagnosis. The study by Bassiony and co-authors (7) described the echogenecities of the ultrasound as hyperechoic (brighter), isoechoic (equal), hypoechoic (darker), anechoic (no internal echoes), or mixed as compared to the adjacent tissues (7). Normal skin on an ultrasound has a very organized pattern where the dermis and epidermis appear as a single hyperechoic and bright layer relative to the subcutaneous tissue, which is hypoechoic (Ramirez-Schrempp). The echogenecities described by Bassiony et al. (7) were the key to staging the infections from the acute phase to the complete abscess formation phase in their study. The phases included edematous changes, cellulitis, preabscess, and abscess stage. They described the echogeneicities of the tissues in the edematous phase as isoechoic, similar to the normal or uninfected side but with an increase in the fluid content. In cellulitis, the tissues were hyperechoic because of the massive inflammatory infiltration to the infected region. In the preabscess stage, the tissues were mixed (hypoechoic and hyperechoic) indicating that the swelling was at the end of the cellulitis stage and at the beginning of the abscess formation stage. In the abscess stage, the echogenicity of the tissues were anechoic (absent) because of the abscess cavity. This cavity can be solitary or multiple well defined foci of pus (7).

Squire et al. (2) described an abscess as a heterogeneic, anechoic, or hypoechoic mass that contains a variable amount of internal echoes. They are usually spherical in shape with poorly defined borders and movement or “swirling”
of the pus may be seen. The cellulitis type of swelling has also been described to show a thickening and diffuse hyperechogenicity commonly referred to as “cobblestoning” (2). The use of color Doppler allows visualization of vascular structures so that they can be avoided during treatment of the swelling (4). Figures 6 and 7 are examples of cellulitis and Figures 8 and 9 are examples of fluctuance as seen on ultrasound in the present study. Figures 10 and 11 are examples of power Doppler and color Doppler images, respectively, as seen in the present study.

In the present study, the swellings were not “staged” because a clear cut diagnosis by clinical exam or by clinical exam plus ultrasound to determine cellulitis or fluctuance was being evaluated. It is not clear in the literature what is expected to be found in the other stages upon surgical intervention. For example, is pus expected to be found in the preabscess stage since it is considered to be between the cellulitis and fluctuance stages? The diagnoses were made based upon whether the operator and expert believed the swellings were mainly in the cellulitis or fluctuance stage (i.e. whether they believed purulence would be expressed upon incision for drainage or not). It is possible that most swellings are a combination of the two making diagnosis very difficult. Making a clear cut diagnosis or knowing the stage of the swelling is important if the treatment of the swellings is different. It is not believed that “staging” would have made much of a difference in the results of this study because clinical exam and ultrasound plus clinical exam were reasonably accurate. It will be discussed in more detail later as to whether the addition of the ultrasound is worthwhile to the clinician.
Eighty-two adult patients participated in this study; thirty-six were female (43.9%) and forty-six were male (56.1%) (Table 2). The distribution consisted of patients who presented to the dental clinic with odontogenic swelling and it is important that this distribution is near equal. Liddel and Locker found that women are significantly more affected by pain, have a lower acceptance of pain, a greater fear of pain, and avoid pain more than males (68). Fillingim et al. also found that women had significantly lower thresholds for the detection and tolerance of pain (69). However, no studies were found on if gender affects diagnosing cellulitis and fluctuance. It was important that our distribution was equal to rule out differences based on gender.

Table 1 shows that the mean age was 37.2 +/- 13.6 years old. There are no studies that show if age has an impact on diagnosing cellulitis or fluctuance. A study by Cachovan et al. found the mean age of patients presenting to the emergency department with odontogenic infections in an 8 year epidemiologic analysis to be 34.8 +/- 16.8 years and showed that patients in the 20-29 range age group utilized emergency care more frequently (67). Table 1 also shows that the mean initial pain rating was 108.9 +/- 40.5 mm, which is at the high end of the moderate scale on the Heft-Parker visual analog scale. As stated previously, the pain associated with a cellulitis is often described by patients as more severe and generalized than the localized pain associated with an abscess (OMFS). While the fluctuant group did have slightly more patients rate their pain as moderate and the cellulitis group had slightly more patients rate their pain as severe, the numbers were close. Once again, this suggests that the
majority of swellings were painful and pain may not be a useful indicator as to differentiating the type of swelling.

It has been suggested that cellulitis tends to indicate a more severe infection and may also have systemic involvement (6). Peterson et al. has stated that patients with systemic infections often have elevated temperatures (6). However, the average patient’s temperature was found to be 98.7° F in this study. Only two patients had a temperature above 100° F. One patient was found to have a cellulitis and the other had a fluctuance upon incision for drainage. This is consistent with the findings from Campanelli et al. that showed vital signs, including temperature, were not affected by swellings (66). This suggests that temperature may not be a good indicator of whether a swelling is a cellulitis or fluctuance.

When a central area of pus was believed to be seen on the ultrasound, several measurements were recorded. The depth was recorded from the top of the screen (which was the skin surface) to the central hypoechoic or anechoic area. Fifty-two swellings were measured for depth and the mean was 12.8 +/-3.4 mm. This was used as a guide for the incision for drainage procedure. A limitation of using this measurement was that it was measured from outside of the mouth on the skin surface and the incision was done intraorally. Therefore, it was only an approximation. This method may be more useful in cases where ultrasonically guided aspiration techniques are used. Incision for drainage was chosen for this study because it is the most commonly used method in dentistry for draining an odontogenic swelling. When a purulence pocket was suspected, the width and
height of the pocket were recorded. The mean width was 20.1 +/- 6.6 mm and the mean height was 6.5 +/- 3.2 mm. Width referred to the anterior-posterior extent of the swelling. Height referred to the surface of the skin to bone extent of the swelling. This was also used to help identify the extent of the pocket or area to be drained. No studies have been found in the literature that suggests a correlation between the size of the pocket and the type of fluid found inside. It would be interesting to investigate whether the size of the pocket indicates the type of fluid (i.e. purulence or blood) in a future study.

Table 2 lists preoperative variables for all subjects. Swellings were seen in the maxilla in 38 patients (46.3%) and the mandible in 44 patients (53.7%). Thirty-eight patients (46.3%) had left-sided swelling and 44 patients (53.7%) had right-sided swelling. Thirty subjects (37%) reported taking antibiotics. Of these, 18 were found to be fluctuance with incision for drainage. Knowing that fluctuance is the more chronic phase, there was an expectation that those patients on antibiotics may be the ones diagnosed as fluctuance. However, many patients did not report being on the antibiotics very long. Most stated only a day or two. The antibiotic may not have had a chance to work and hence many of the patients were still in the cellulitis stage. Another concern was the length of time the patients were swollen. This too could have played a role in the stage of the swelling. However, obtaining histories from patients may not always be an accurate measure. There are many times in clinical practice when patients report “swelling” and it is not seen clinically. Patients were routinely asked as part of the clinical exam but many were not completely sure as to when the swelling began. Therefore, due to the inability
to definitively know when the swelling began, it was not recorded on the data sheet and was not evaluated in this study. However, it may be useful to do a study that follows the course of the swelling to assess the outcome of different treatments and also to assess what time period, if any, a cellulitis may turn into a fluctuance. Overall, 14 teeth (17.1%) associated with the swellings were maxillary anterior, 24 (29.3%) were maxillary posterior, 3 (3.7%) were mandibular anterior, and 41 (50%) were mandibular posterior. As found by Cachovan et al., the maxillary and mandibular first molars are the most significantly affected teeth and primary sites of odontogenic infection (67). Therefore, it is not uncommon that these teeth make up the majority of the teeth that caused swelling.

In this study, the swellings were mainly seen in the vestibular, buccal, and labial spaces. Swellings were also seen in the submandibular space and the infraorbital space, but usually as a secondary space. A vestibular abscess is the most common odontogenic infection. An infection generally tends to erode through the thinnest cortical plate (6). The maxillary buccal vestibular space is involved when a posterior maxillary tooth is the source of infection (5). When the infection from maxillary posterior teeth erodes through the bone superior to the buccinator muscle attachment then the buccal space is involved and when it is inferior to the buccinator muscle then the vestibular space is involved (5, 6). The mandibular buccal vestibular space is the space that lies between the buccal cortical plate, the overlying alveolar mucosa, and the buccinator muscle in the posterior and the mentalis muscle in the anterior. When the infection from a mandibular posterior tooth erodes through the bone superior to the buccinator muscle than the vestibular
space is involved and when it is inferior to the buccinator than the buccal space is
involved. The canine (or infraorbital) space is located between the levator anguli
oris muscle inferiorly and the levator labii superioris muscle superiorly. The
primary tooth involved is the maxillary canine; however, the maxillary first
premolar may also be responsible (5, 6). Obliteration of the nasolabial fold is often
seen when this space is involved (6). The maxillary central incisor is primarily
responsible for swellings at the base of the upper lip. The apex of the tooth lies
above the orbicularis oris muscle attachment (5).

Swellings that were unable to be viewed with the ultrasound (i.e. palatal or
lingual swellings) were excluded. The probe was only used extraorally. This is
because when it was attempted to be used intraorally, it was too large for most
patients and the image quality was poor. A smaller probe was tried, but it too did
not produce good resolution images. This may be due to the fact that the surface
was oral mucosa and not skin. Transducer gel could not be used intraorally to
prevent the trapping of air bubbles between the probe and the mucosa. Saliva was
used to wet the probe but that did not help improve the images. More investigation
and research needs to be done on using the probes intraorally. An intraoral probe
could improve on measurements for drainage if a good image could be attained.
Only fascial spaces that were able to be reached for an intraoral incision for
drainage were included. Patients were excluded from the study if the swelling was
thought to be life threatening and possibly require airway management and/or
hospitalization, i.e. Ludwig’s angina and cavernous sinus thrombosis, or if the
patient stated that he/she was having difficulty swallowing or breathing.
Table 3 shows the tooth type and gender grouped by cellulitis and fluctuance. For the cellulitis group, 5 teeth (16.7%) were maxillary anterior, 7 (23.3%) were maxillary posterior, 0 were mandibular anterior, and 18 (60%) were mandibular posterior. For the fluctuant group, 9 teeth (17.3%) were maxillary anterior, 17 (32.7%) were maxillary posterior, 3 (5.8%) were anterior mandibular, and 23 (44.2%) were mandibular posterior. The cellulitis group had 14 females (46.7%) and 16 males (53.3%) and the fluctuant group had 22 females (42.3%) and 30 males (57.7%). A greater number of fluctuance was found in this study. This may be because patients with significantly large or more severe swellings often present to emergency departments at a hospital while those with localized swellings may present to a dental clinic for treatment. Also, all patients that presented with facial swelling and met all inclusion criteria were enrolled in this study. Therefore, whoever showed up was included and it was not required to have half the patients with fluctuance and half with cellulitis.

This study used incision for drainage as the standard in determining cellulitis or fluctuance because it is the most common method used by dentists. If purulence (pus) was expressed after the incision for drainage, the swelling was classified to be a fluctuant swelling. If purulence (pus) was not expressed then the swelling was classified a cellulitis. Table 4 shows that the number of swellings determined to be cellulitis or fluctuance, found after incision for drainage, were 30 (36.6%) and 52 (63.4%), respectively. There is very limited information on the incidence of cellulitis and fluctuant swellings in the literature. Of the articles reviewed only two provided an incidence. Squire et al. (2) sought to determine
whether the addition of bedside ultrasonography would increase the diagnostic accuracy for detecting superficial subcutaneous abscesses. The prospective study included 107 patients who presented with a chief complaint suggestive of cellulitis or abscess. Sixty-four (59.8%) patients had incision and drainage proven abscess and 17 (15.9%) had negative incision and drainage and therefore cellulitis. The remainder either refused incision and drainage and/or were lost to follow-up (2). Peleg et al. (3) studied 50 patients with acute odontogenic infections of the superficial fascial space. Twenty-four patients had buccal swelling, 15 had submandibular swelling, 4 had sublingual swelling, 2 had periorbital swelling, and 5 had infraorbital swelling as diagnosed clinically. After clinical and radiographic examination, an ultrasound was used to examine the infected area and an ultrasonically guided needle aspiration was performed. Fluid was identified by ultrasound in 22 (44%) of the 50 patients and aspiration of pus was positive in all of these patients. Twenty-eight patients (56%) were determined to have cellulitis.

A higher incidence for fluctuance was found in the present study compared to Peleg and co-author’s (3) findings and only a slightly higher incidence than Squire and co-author’s (2) findings. The incidence for cellulitis in this study was higher than that found by Squire et al (2). This is most likely due to the fact that the percent of fluctuance and cellulitis did not add up to 100% in the Squire study due to 26 patients that were either not incised and drained or lost to follow up. It is possible that more of the patients may have been diagnosed as cellulitis. Also, the swellings were cutaneous swellings and the difference in location may also explain the difference in incidence. The incidence of cellulitis in the present study was
lower than that found by Peleg et al (3). A reason for this may be that a different standard was used to determine the presence of pus. An incision for drainage was used in this study and an ultrasonically guided needle aspiration in the Peleg et al. study (3). It may have reached the pus pocket more accurately. More evidence based research should be done on the appropriate method of treatment.

Table 4 demonstrates the number of cellulitis versus fluctuant type swellings recorded with clinical exam alone, clinical exam plus ultrasound, findings after incision for drainage (which were reported above and used as the standard), ultrasound diagnosis alone, and the expert ultrasound diagnosis alone. With clinical exam alone, a diagnosis of cellulitis was made 14 out of 82 times (17.1%) and a diagnosis of fluctuance was made 68 out of 82 times (82.9%). With clinical exam plus ultrasound, cellulitis was diagnosed 19 out of 82 times (23.2%) and fluctuance was diagnosed 63 out of 82 times (76.8%). Table 5 shows that with clinical exam alone a correct diagnosis was made 56 of 82 times (68.3%) and that with clinical exam plus ultrasonography a correct diagnosis was made 57 of 82 times (69.5%). Only one more correct diagnosis was attained by adding ultrasonography and it was not statistically significant (p > 0.05).

There are a couple of plausible explanations as to why there was no difference between the two methods in correctly identifying the diagnosis. One is that the operator may have had additional information from the clinical exam when making the diagnosis by ultrasound. It is impossible to separate the two during patient treatment. To address this issue, the investigator reviewed all the images at the end of the study, in a randomized order, and determined a diagnosis without the
patient being present to compare the accuracy of the ultrasound alone. Randomization and blinding was done by another operator. One week later, the images were re-randomized and a diagnosis was made to address viewer reliability. However, if dentists were to use the ultrasound as an adjunct to clinical exam, the patient would almost always be present. It would be very unlikely and not practical to send the readings out to a radiologist. This would lead to delay in treatment, which is not in the best interest for the patient. Regarding the training of the investigator in the current study, Squire et al. (2) showed that ultrasonography is easy to use and after only a 30 minute didactic and hands-on training session, emergency physicians and residents were able to accurately differentiate between abscess and cellulitis. The didactic portion of the training consisted of images and video clips of abscesses and cellulitis and the hands-on portion allowed the physicians and residents to scan on healthy volunteers (2). The operator in this study had a trained ultrasound technician spend one day explaining how to operate the machine. Another day was spent with a trained radiologist in differentiating between cellulitis and abscess on patients. It is believed that the operator in this study was trained well enough to evaluate the images. To address this issue, an expert radiologist also reviewed the images, at the end of the study, without the patients present, in a randomized order, and a diagnosis was made to compare the accuracy to the investigator. The expert then viewed the images one week later after they were randomized again to address reliability. The results of the reliability of the investigator and expert are discussed later.
The investigator, using the ultrasound alone, made the diagnosis of cellulitis 22 out of 81 times (27.2%) and a diagnosis of fluctuance 59 out of 81 times (72.8%) (Table 4). The expert, using the ultrasound alone, diagnosed cellulitis 29 of 81 times (35.8%) and fluctuance 52 of 81 times (64.2%) (Table 4). These numbers do not indicate percent correct for the ultrasound alone by operator and expert. They show only the number diagnosed in each category. Overall, fluctuance was diagnosed more frequently for all methods, which is consistent with the incidence as fluctuance was found more often with incision for drainage. The total number for the ultrasound readings alone was 81 which is one short of that with clinical exam and clinical exam plus ultrasonography. This is because one of the patient’s images was not retrievable from the computer.

Table 6 shows the statistical analysis of the data. True positives were detecting cellulitis when it was found to be cellulitis upon incision for drainage. True negatives were not detecting cellulitis when cellulitis was not found upon incision for drainage, meaning fluctuance was found. Clinical exam detected true positives (cellulitis) 9 out of 30 times (30%). Clinical exam plus ultrasonography detected true positives 12 out of 30 times (40%). True positive detection with the ultrasound images alone by the investigator and ultrasound images alone by the expert were 10 out of 30 (33%) and 16 out of 30 (53.3%), respectively. Therefore, the ultrasound did detect more true positives (cellulitis) than clinical exam alone. This may be because the ultrasound has the advantage of detecting “cobblestoning” which cannot be assessed with clinical exam alone. However, it still only identified less than half of the cellulitis. This suggests it may be difficult to diagnose cellulitis
regardless of method. Whether or not this slight increase in the number of cellulitis diagnosed by ultrasound is beneficial clinically is questionable. The cost/benefit analysis of the ultrasound will be discussed after all results are thoroughly presented.

Clinical exam alone detected true negatives (fluctuance) 47 out of 52 times (90.4%) and clinical exam plus ultrasonography detected true negatives 45 out of 52 (86.5%). Detection of true negatives with ultrasound images alone by the operator and ultrasound images alone by the expert were 40 out of 52 (77%) and 39 out of 52 (75%), respectively. The detection of fluctuance was higher with all methods but highest with clinical exam. Therefore, ultrasound is not more useful than clinical exam alone in detecting fluctuance. With clinical exam there is the added benefit of feeling the swelling and detecting the soft fluid filled cavity. False positives (meaning a diagnosis of cellulitis was made when it was found to be fluctuance upon incision for drainage) were detected by clinical exam, clinical exam plus ultrasonography, ultrasound alone by operator, and ultrasound alone by expert, 6.1%, 8.5%, 14.8%, and 16% of the time, respectively. Low false positives are important if following the guidelines to incise and drain a fluctuant swelling and medicate a cellulitis with antibiotics (2, 3, 4). Having a high false positive and detecting cellulitis when it is actually fluctuance would lead to inappropriately draining a fluctuance or possibly over-prescribing antibiotics. According to the “Pathways of the Pulp” textbook, antibiotics are recommended only in cases of progressive or persistent infections with systemic signs and symptoms such as fever, malaise, cellulitis, unexplained trismus (5). As listed in the summer 2006
Endodontic Colleagues for Excellence article, adjunctive antibiotics should be administered if a patient has one or a combination of the following: “fever > 100°F, malaise, lymphadenopathy, trismus, increased swelling, cellulitis, osteomyelitis, and/or persistent infection” (47). The conditions not requiring antibiotics are; “pain without signs and symptoms of infection (symptomatic irreversible pulpitis and symptomatic acute periodontitis), teeth with necrotic pulps and a radiolucency, teeth with a sinus tract (chronic periradicular abscess), and localized fluctuant swellings.” However, as stated before, the decision on incision and drainage is controversial and some authors recommend draining both fluctuance and cellulitis (5, 6, 47). The low false positives would not be as important if both conditions are to be drained. False negatives (meaning a diagnosis of fluctuance was made when it was found to be cellulitis upon incision for drainage) were detected by clinical exam, clinical exam plus ultrasonography, ultrasound alone by operator, and ultrasound alone by expert, 25.6%, 22%, 23.5%, and 16% of the time, respectively. In this case, false negatives would not be wanted because patients may undergo unnecessary incision for drainage or not be appropriately prescribed antibiotics for cellulitis.

The results of this study found the sensitivity (the ability to detect cellulitis when it was cellulitis) of the clinical exam alone was 30% and for clinical exam plus ultrasonography was 40% (Table 6 and Figure 1). When using ultrasound images alone by the investigator and expert, sensitivity was 34.5% and 55.2%, respectively (Table 6 and Figure 1). This may be due to the fact that diagnosing cellulitis is difficult with all methods. The specificity (the ability to not detect
cellulitis when cellulitis is not present) was 90.4% for the clinical exam alone and 86.5% for the clinical exam plus ultrasonography (Table 6 and Figure 2). The specificity for ultrasound images alone by the investigator and expert were 76.9% and 75%, respectively (Table 6 and Figure 2). These numbers are higher indicating that detecting fluctuance may be easier with all methods. The positive predictive value is the “proportion of patients with positive test results who have the target disorder” and the negative predictive value is the “proportion of patients with negative test results who do not have the target disorder” (14). In this case, the positive predictive value would be the proportion of patients with a positive test result of cellulitis that indeed have cellulitis. The negative predictive value would be the proportion of patients with a negative test result of fluctuance that indeed have fluctuance. Table 6 and Figure 3 show the positive predictive values as 64.3% for the clinical exam alone, 63.2% for the clinical exam plus ultrasonography, 45.5% for ultrasound diagnosis alone by the investigator, and 55.2% for ultrasound diagnosis alone by expert. The negative predictive values are 69.1% for the clinical exam alone, 71.4% for the clinical exam plus ultrasonography, 67.8% for ultrasound diagnosis alone by the investigator, and 75% for ultrasound diagnosis alone by expert (Table 6 and Figure 4). The values of accuracy are 68.3% for the clinical exam alone, 69.5% for the clinical exam plus ultrasonography, 61.7% for ultrasound diagnosis alone by investigator, and 67.9% for ultrasound diagnosis alone by expert (Table 6 and Figure 5). The accuracy is similar for all methods and all data points are within the confines of the 95% confidence limits. The accuracy
was not 100% and so improvement in diagnosis is needed. Therefore, this data suggests that all methods are similar.

Table 7 reports the reliability coefficient of the investigator and the expert. At the completion of data collection, the images were randomized and the investigator viewed the images and recorded a diagnosis without the patient present. One week later, the images were re-randomized and the investigator recorded a diagnosis. This was done to address the investigator’s reliability. An expert radiologist also reviewed the images twice without the patient present and recorded a diagnosis to compare accuracy to the operator. The reliability coefficient is kappa (k). A kappa from 0 to less than 0.4 is considered marginal reproducibility. A kappa between 0.4 and 0.75 is considered good reproducibility and a kappa greater than 0.75 is considered excellent reproducibility. A kappa of 1 means 100% reliability (59). The investigator was found to have excellent reliability (k = 0.81) while the expert showed marginal reliability (k = 0.32). A reason for the investigator having better reliability may be because the investigator had been viewing the images throughout the study period as related to cellulitis and fluctuance, which may be more focused than the expert who reads multiple types of images for differing reasons on a daily basis. The expert may have had a difficult time of strictly differentiating between cellulitis and fluctuance because of his ability to interpret the different stages between the two. Also, in a dental practice the ultrasound images would never be viewed without the patient present for reasons previously discussed.
Overall, the findings of this study suggest that ultrasonography may not be useful as an adjunct to clinical exam in differentiating between cellulitis and fluctuance. This contradicts many of the other studies done using ultrasound as an aid. A review article by Ramirez-Schrempp, et al. (4) stated “Ultrasound is an efficient, noninvasive diagnostic tool which can augment the physician’s clinical examination. Ultrasound has been shown to be superior to clinical judgment alone in determining the presence or the absence of occult abscess formation, ensuring appropriate management, and limiting unnecessary invasive procedures” (4). The authors of this review article concluded the above statement but only took into account three articles in differentiating cutaneous cellulitis and abscess. The article by Squire and co-authors and Tayal et al. were two of the three and shall be thoroughly discussed later. However, ultrasound may work well for cutaneous swellings. The present study was evaluating odontogenic swellings specifically.

The studies and case reports in the medical literature utilized ultrasound guided aspiration and irrigation techniques to locate and treat breast, thyroid, and prostate abscesses over traditional surgical drainage techniques (9, 10, 12, 13). They all concluded that ultrasound guided aspiration techniques are successful and should be considered. These studies are different than this current study in that they were looking at the treatment of abscesses. The current study was attempting to differentiate between cellulitis and fluctuance. Also, incision for drainage was used as the standard to determine the definite diagnosis in the current study and in the medical literature ultrasonically guided aspiration techniques were used to treat abscesses. Ultrasonically guided aspiration techniques may be a more accurate
method to reach a suspected purulent site because it can be measured and then seen on ultrasound if the site is reached. Unfortunately for dentistry, that would mean going through the extraoral skin to reach the swelling which may not be practical for all practitioners. An intraoral approach with an intraoral probe may be the answer. However, as stated before, the images viewed with an intraoral probe did not have good resolution and were not of diagnostic quality. More research needs to be done in this area. The study by Ozeker et al. used ultrasound to detect and evaluate the treatment of ultrasonically guided aspiration techniques in only 11 breast abscesses (9). This number is very low and therefore the study appears to be underpowered. They concluded that this method is more successful in abscesses with a maximum dimension smaller than 3 cm and that it should be preferred to surgical drainage which requires general anesthesia and leads to a poorer cosmetic result (9). The present study did not follow up on treatment outcomes to assess healing of the swellings nor if size of the suspected abscess had an impact on treatment. It would be interesting to do another study to look at treatment modalities comparing ultrasonically guided aspiration techniques to incision versus drainage techniques to no drainage at all to assess healing. Would simply completing root canal therapy or extracting the tooth and prescribing the appropriate antibiotic, if necessary, lead to healing? This may lead to elimination of unnecessary procedures and may be beneficial because it is known that incision for drainage is very painful. Singer and co-authors found that incision and drainage of an abscess in a medical emergency department was the second most painful procedure performed after nasogastric intubation (46). Also, investigating on
whether the size of the lesion has an impact should be studied. The study with Leborgne and Leborgne (10) treated more patients (67) and found a cure rate of 96%. They injected cefradine, a first generation cephalosporin, into the abscess cavity if it measured more than 25 mm. However, 26 patients had to undergo treatment 2 or more times (10). Possibly, the addition of the antibiotic contributed to healing. The use of an antibiotic was not evaluated in the present study. Neither the Ozseker study (9) nor the Leborgne and Leborgne study had a control group that underwent traditional surgical drainage techniques (10). The case reports by Ilyin (12) and Somuncu (13) only reported two cases of thyroid abscesses treated successfully with sonographically guided fine needle aspiration and one case of prostate abscess treatment with ultrasound guided transrectal needle aspiration, respectively (12, 13). These case reports give promise to the technique but well designed controlled studies are needed. However, the present study was focused primarily on diagnosing cellulitis and fluctuance and not on effective methods of treatment. Again, more evidence-based research is needed.

The study by Squire et al. (2) sought to determine whether the addition of bedside ultrasonography would increase the diagnostic accuracy for detecting superficial subcutaneous abscesses. This prospective study included 107 patients who presented with a chief complaint suggestive of cellulitis or abscess. They found that the sensitivity of clinical examination for abscesses was 86% and the specificity was 70%. The sensitivity of ultrasound examination for abscesses was 98% and the specificity was 88%. Ultrasound and clinical examination disagreed in 18 of the cases and 17 out of the 18 (or 94%) were correctly identified by the
ultrasound. The positive predictive value for clinical exam and ultrasound was 81% and 93%, respectively. The negative predictive value for clinical exam and ultrasound was 77% and 97%, respectively. All patients that were considered to have an abscess prior to the ultrasound reading were treated with needle aspiration or incision and drainage. The rest of the patients were treated at the physician’s discretion. The standard criterion for abscess in patients who underwent the drainage procedure was the demonstration of pus. For those patients who did not receive drainage, the resolution of symptoms at a seven-day follow up telephone call was a criterion standard for absence of abscess. Sixty-four patients has incision and drainage (I&D) proven abscess, 17 had negative I&D, and 26 had improved with antibiotics alone (2). This study is flawed because there was not one standard criterion. All patients should have been drained to keep the experiment controlled. There is no support in the literature to suggest that the resolution of symptoms indicates an abscess was not present. The antibiotics may have contributed to the healing. Also, the patient’s immune system may have resolved the infection. Many times no treatment at all will lead to healing. The other flaw is that one technique for drainage should have been used to keep the study well controlled. The incision may have penetrated a greater area or the needle may have reached a greater depth. In cases of multiple loculations or combination lesions, this may present a problem. Also, this study was different from the current study in that abscess was used as the positive response where, in the current study, cellulitis was the positive response. This affects how the values are interpreted. The values of sensitivity and specificity should be inverted to compare and has been done as follows. They found that the
sensitivity of clinical examination for abscesses was 86% and the specificity was 70% (2). The specificity (ability to not detect cellulitis, therefore fluctuance) of the current study was 90.4% for clinical exam only and sensitivity (ability to detect cellulitis, not fluctuance) was 30% for clinical exam alone. The current study’s detection of fluctuance (or abscess) by clinical exam are closer to those of Squire et al. (2), however, the ability to detect cellulitis was much lower. The sensitivity found by Squire et al. of the ultrasound examination for abscesses was 98% and the specificity was 88% (2). The current study found the specificity (ability to not detect cellulitis, therefore fluctuance) of clinical exam and ultrasound to be 86.5% and the sensitivity (ability to detect cellulitis, not fluctuance) to be 40%. Again, the ability of the current study, using clinical exam and ultrasound, to detect fluctuance was closer to that found by Squire and co-authors (2) but the ability to detect cellulitis was lower. These differences may be attributed to the fact that one standard criterion was not used in the Squire et al. (2) study and many of their patients were not drained to determine a definite diagnosis. Also, they were viewing subcutaneous swellings and the present study was viewing orofacial swellings. The difference in the site of the swelling may have also contributed to the different results. It may be easier to use the ultrasound probe on one surface versus the other and therefore obtain better images. It may be easier to drain and visualize a swelling on the skin versus inside of the oral cavity.

In the study by Tayal et al. (15), the effect of ultrasound on the management of emergency department patients with clinical cutaneous cellulitis or those without obvious abscess was evaluated. A total of 126 patients were enrolled in this study.
In 56% (71/126) of the cases, ultrasound changed the management of patients with cellulitis. In the group that was believed to have cellulitis and not need drainage, ultrasound changed the management in 48% (39/82) of the cases with 33 patients receiving drainage and 6 requiring further consultation. In the group that was believed to require drainage, ultrasound changed the management in 73% (32/44) of the cases which included 16 in which drainage was eliminated and 16 who required further consultation. They concluded that the ultrasound changed management in about half of the patients who presented to the emergency department with clinical cellulitis. They also concluded that it may guide management by detecting occult abscess, guidance for further consultation or imaging, or the prevention of invasive procedures (15). While this study shows that management was changed, there was no information provided to indicate whether or not the change was the appropriate treatment or whether ultrasound was accurate in differentiating cellulitis and fluctuance. Again, their study evaluated cutaneous swellings and the present study evaluated orofacial swellings which may have lead to different findings and conclusions. Also, there was no standard criterion in the Tayal et al. (15) study. A definite diagnosis of cellulitis or abscess could not have been made for those that were not drained. Of the 63 patients believed to have fluid collection on ultrasound, 58 patients had a drainage procedure. The drainage was by incision, aspiration, or a combination of both. Again, for control, only one method should have been used. For those swellings that were drained, there were 54 patients who had fluid recovered and it included 46 with purulent collections (pus), 4 serous collections, 2 with hematomas, and 2 with bloody serous collections. The other 5 had no fluid
upon drainage and were discharged (15). This brings up the issue that just because fluid is seen on ultrasound, it may be hard to determine what type of fluid. An abscess is considered a pus-filled cavity (6). If the type of fluid cannot be distinguished on ultrasound then can a definite diagnosis of abscess be made? This was an issue with the present study. There were situations when an anechoic area was seen on the ultrasound, indicating a pus pocket, but when it was incised only blood was expressed. It may have been a hematoma or just bloody serous collection.

In a study done in 1987 by Ralf Siegert (16), the use of ultrasound was investigated in the diagnosis of inflammatory soft tissue swellings of the head and neck region as compared to clinical examination. The final diagnosis was determined on the basis of either surgical intervention or resolution due to nonsurgical treatment. A definitive diagnosis could not be made for the swellings that resolved due to nonsurgical treatment. Seventy-nine patients were examined in the study. Five classes were assigned to the ultrasound images. Class I was edema and 3 patients (4%) were found to fall into this category. It is characterized by enlargement of anatomical structures and slight echoreduction. Class II was the infiltrate category in which 24 patients (30%) were grouped. The images appeared as a diffuse area of increased echointensity and anatomical structures were difficult to delineate. The preabscess category, class III, showed an infiltrate in which there was slight or not well delineated echoreduction. Twelve patients (15%) were placed into this category. Class 4 and 5 were considered to be the abscess category and included 40 patients (51%) who were split into two types. Type I (33%) had
echo-free internal structures and type II (18%) were echo-poor. An abscess appeared as a delineated area with posterior enhancement. The sensitivity for diagnosing an abscess clinically and with ultrasound was found to be the same, 93% if the uncertain and questionable (preabscess) category were included. However, ultrasonography did have a higher sensitivity of 82% versus clinical exam of 69% when only the specific diagnosis of abscess was considered (16). The latter figures should be used to compare to the present study as preabscesses were not a diagnostic category. In the Siegert study, the specificity of ultrasound was 86% if preabscesses were included and 71% if not (16). For clinical examination, the specificity was 65% if preabscesses were included versus 43% if not (16). Again, the figures not including preabscesses, should be used to compare to the present study. Siegart also used abscess as the positive response and therefore should be taken into consideration when comparing the numbers to the current study’s findings. The Siegert study had a higher incidence of fluctuant swellings with clinical examination and ultrasound examination which is similar to what was found in the present study. He concluded that ultrasonography should be used to supplement clinical exam in patients with head and neck swellings and can be used to follow the course of the infection and its response to nonsurgical treatment (16). Again, because no standard criterion existed, it is difficult to make that conclusion.

In the study done by Adhikari et al. in 2011 (17) records were reviewed of patients who presented to the emergency department with an odontogenic problem where a panoramic radiograph and bedside ultrasound were performed. A total of 19 patients were identified and the purpose of the study was to compare the two
techniques in the diagnosis of a dental abscess. The number of patients in this study is low and therefore suggests this study was underpowered. In 7 of the 19 patients, no periapical abscess was reported on the panoramic radiograph. In 6 of the 7 cases, ultrasound agreed with the panoramic radiograph. In the one case of disagreement, an incision and drainage was performed and the presence of an abscess was confirmed. A diagnosis of periapical abscess was made by the panoramic radiograph in 12 of the 19 cases and ultrasound agreed with 10 out of the 12. One patient was lost to follow up but the authors assumed this patient had a dental abscess. They found the sensitivity and specificity of the ultrasound to diagnose a dental abscess were 92% and 100%, respectively (17). This study is flawed because an abscess cannot be determined by a panoramic radiograph. A panoramic radiograph is a two-dimensional image and cannot show infection in fascial spaces. An abscess is a pus filled cavity (6). Without surgical intervention to determine if pus is present, it cannot be accurately diagnosed. Also, without this standard criterion, the findings on the ultrasound cannot be confirmed. The diagnosis of abscess cannot accurately be made. They used the panoramic radiograph to determine if an abscess was present based upon whether or not a radiolucenty was present. There have been studies that show a panoramic radiograph is not a useful diagnostic tool in evaluating periapical pathoses (60, 61). A study by Molander (61) assessed the agreement between panoramic and intraoral radiography in diagnosing periapical pathosis, bone levels, and caries. They evaluated 400 patients and found the average agreement between intraoral and panoramic radiographs to be 55% for the rotation and 46% for the intraoral tube.
technique in periapical diagnosis. They concluded that a panoramic radiograph is not sufficient for diagnosing periapical pathoses (61). A study done by Roushton and Roushton (60) found that of 740 panoramic, 1418 bitewing, and 325 periapical radiographs assessed, only 32 panoramic films provided additional diagnostic value. They found that the panoramic radiograph significantly overestimated the presence of periapical pathosis (60).

Bassiony and co-authors (7) investigated ultrasonography as an alternative to magnetic resonance imaging (MRI) in the detection of fascial space spread of odontogenic infections. Forty-two fascial spaces in 16 subjects were examined by ultrasonography and the results were confirmed by MRI and microbiologic tests through aspiration, incision and drainage, or after extraction of the teeth. The ultrasound successfully identified 32 (76%) of the 42 spaces and there was 100% agreement with the MRI. The ultrasound detected buccal, submandibular, canine, submasseteric, submental, and infraorbital involvements. It was unable to detect masticator, parapharyngeal and sublingual space involvements. The ultrasonography proved helpful in staging the infections from edematous changes to cellulitis to abscess formation (7). In the present study, the swellings were not “staged” because a clear cut diagnosis by clinical exam or by clinical exam with the use of ultrasound to determine cellulitis or fluctuance was being evaluated. The diagnoses were made based upon whether the operator and expert believed the swellings were mainly in the cellulitis or fluctuance stage (i.e. whether they believed purulence would be expressed upon incision for drainage or not). It would be interesting to further investigate the staging of infections and what would be
found microscopically in each stage. For example, since the preabscess stage is considered to be between the cellulitis and fluctuance stage, would purulence be expressed upon incision and drainage? It was not clearly stated as to whether purulence was found in the preabscess stage or not in the Bassiony et al. (7) article. The authors did show ultrasound images of the stages. In the present study, it did appear that many of the swellings were in the mixed staged and that may be the reason the findings of sensitivity and specificity are lower than other studies. However, if treatment does not differ, then is staging important? More research needs to be done on this subject. Bassiony and co-authors (7) concluded that ultrasonography may be useful in detecting and staging the spread of odontogenic infections in superficial fascial spaces, however deep fascial spaces may be difficult to detect (7). This was important in the decision on which fascial spaces to include in the present study. Therefore, deeper spaces were not included.

Peleg et al. (3) also showed that ultrasonography is an effective aid in the staging of an infection and in confirming abscess formation in the superficial fascial spaces. They studied 50 patients with acute odontogenic infections of the superficial fascial space. Twenty-four patients had buccal swelling, 15 had submandibular swelling, 4 had sublingual swelling, 2 had periorbital swelling, and 5 had infraorbital swelling as diagnosed clinically. After clinical and radiographic examination, an ultrasound was used to examine the infected area and an ultrasonically guided needle aspiration was performed. Fluid was identified by ultrasound in 22 of the 50 patients and aspiration of pus was positive in all of these patients. Six of the patients diagnosed as cellulitis had a repeat scan done three
days later. Four of the six patients were diagnosed as having an abscess on the third day. They concluded that ultrasonography is a quick, widely available, painless, and inexpensive adjunct. It can be repeated numerous times without risk to the patient to aid in the staging and diagnosing odontogenic infections (3). This study most closely resembled our study in that all patients had a drainage procedure to determine the presence of purulence. In the study by Peleg et al. (3), needle aspiration was used to determine if purulence was present. They did not have as many patients as the present study. However, they found ultrasound and the aspiration of pus coincided 100% of the time. Our accuracy was lower for all methods ranging from 61.7% (ultrasound by operator alone) to 69.5% (clinical exam plus ultrasound). It may be due to the fact that needle aspiration is a better method to reach the purulence. More research needs to be done to investigate whether needle aspiration or incision and drainage should be used as the standard or if both are equally acceptable. The present study chose incision for drainage because it is the most common method used in dentistry to drain swellings. Also, as mentioned before, with the use of an extraoral probe and measurements from the skin surface, it would not be practical to aspirate from an extraoral method in dentistry. The use of an intraoral probe did not provide good diagnostic quality images to allow for an intraoral aspiration guided technique. The study by Peleg and co-authors (3) also did not compare ultrasound examination to clinical examination as did the present study. Therefore, we cannot compare their ability to diagnose abscesses clinically. They may also find that the accuracy of clinical examination and ultrasound examination are similar. If most swellings considered
cellulitis became abscesses after the third day, as shown by Peleg et al. (3), then perhaps clinical history may aid in diagnosis. In the present study, clinical history was taken into account upon examination but was not examined as a measure for diagnosis. It was not quantified into specific hour or days. This type of patient history may be difficult to verify. The present study was only looking to compare clinical examination to clinical examination plus ultrasonography. It would be interesting to do a study that follows the course of the patient’s swellings.

According to the results of this study, ultrasound was useful in diagnosing cellulitis and fluctuance but was not statistically better in the number of correct diagnoses compared to clinical examination done. Therefore, the cost of adding an ultrasound machine to the dental practice to aid in diagnosis of cellulitis and fluctuance greatly outweighs the benefit. According to this study, clinical exam and ultrasound plus clinical exam were moderately accurate; 68.3% for clinical exam alone vs. 69.5% for clinical exam plus ultrasonography (Table 6). It does not seem practical to invest in an ultrasound at the cost of between $20,000 and $30,000 dollars for a portable machine like the one used in this study.

There are limitations to this study and possible reasons why ultrasound was not more accurate. As stated previously, frequently the two conditions coexist within an odontogenic swelling (2). Multiple authors have described or recognized stages of odontogenic swellings (3, 7, 16). Bassiony et al. described phases that included edematous changes, cellulitis, preabscess stage, and abscess stage (7). Siegart classified the swellings as seen on ultrasound as edema, infiltrate, preabscess, and abscess (16). Because there are so many different classifications
and combination lesions, it suggests the ability to make a clear cut diagnosis of cellulitis or fluctuance is difficult and maybe a “true” cellulitis or fluctuance is rare. Perhaps, due to multiple loculations, our incision and drainage procedure did not reach the area of purulence if it was present. Also, there were situations where the incision was difficult because the swelling was too close to certain anatomical structure (i.e. the mental foramen). Maybe using an ultrasonically guided needle to aspirate would have been more accurate in these situations.

Many images on the ultrasound appeared to be combination lesions. The investigator and expert made a diagnosis on what they believed was more prevalent on the screen. There were cases where cobblestoning, indicating cellulitis, was seen on the surface level with a hypoechoic or anechoic, consistent with fluid, area seen below. Other cases showed what was believed to be a delineated pus pocket and no pus was found upon incision for drainage. This may be because the lesion may have been a collection of serous fluid or a hematoma instead of purulence. As reported by Tayal et al. (15), 54 of the 58 swellings that were believed to have fluid collection actually did have fluid. Of those, 46 were purulent collections (pus), 4 were serous collections, 2 were hematomas, and 2 were bloody serous collections (15). This shows that just because an ultrasound shows an area of possible fluid collection, it doesn’t help to distinguish the type of fluid. Therefore, diagnosing an abscess (a pus-filled cavity) may be difficult with ultrasound.

While magnetic resonance imaging (MRI) and computed tomography (CT) are valuable diagnostic aids (and often considered the gold standard) in imaging soft tissue lesions and the spread of infections into fascial spaces; they are not
readily available in many dental clinics. They are expensive and time-consuming and expose the patient to larger doses of radiation (3, 7). It would not be practical in a dental setting to send a patient out for a scan when often the treatment of the swelling should not be delayed. With the advent of cone-beam computed tomography (CBCT) and its increased use and popularity in the dentistry, it would be interesting to study if CBCT has the advantage of differentiating between cellulitis and fluctuance better than clinical exam alone. It is less expensive and has less radiation than traditional computed tomography (63). However, it still exposes patients to radiation and the concept of ALARA (As Low As Reasonably Acheivable) should be considered. Dentists are also responsible for interpreting the entire CBCT image and are liable for missed diagnoses (64, 65). However, units are now more focused on the mandible and maxilla only.

Our findings show that ultrasound did not improve the clinical evaluation or diagnosis of cellulitis and/or fluctuance. Neither combination, clinical exam alone nor clinical exam plus ultrasonography, were 100% accurate. More evidence based research is needed to investigate the appropriate methodology in determining the diagnosis and the appropriate treatment of swellings. If the treatment of the two types of swellings does not differ, then possibly just identifying all spaces involved is sufficient. Overall, the present study has shown that clinical examination and clinical examination plus ultrasonography are moderately accurate, 68.3% and 69.5%, respectively. But there is still a need for improvement. The results of this study demonstrated that ultrasound did not significantly improve the number of
correct diagnoses. The benefit of adding the ultrasound to clinical examination may not outweigh the cost.
CHAPTER 5
SUMMARY AND CONCLUSIONS

This study investigated the use of ultrasonography as a valuable aid to clinical examination in differentiating between fluctuant swellings (abscesses) and cellulitis. The purpose was to compare the accuracy of clinical examination plus ultrasonography versus clinical examination in the diagnosis of cellulitis and fluctuant swellings in symptomatic patients with a diagnosis of pulpal necrosis, acute apical abscess or cellulitis, and clinical swelling. Studies in both the medical and dental literature suggest that ultrasound is a promising adjunct (2-4, 7, 9-10, 12-13, 15-17). However, as thoroughly discussed, many of these studies were underpowered or were not well controlled research designs. In this study, incision for drainage was used as the standard in making the final diagnosis. The results of this study show that there was no statistical difference between clinical examination alone and clinical exam plus ultrasonography in making the correct diagnosis. The sensitivity, specificity, positive predictive, negative predictive, and accuracy were very similar for all methods tested.

From the results of this study, ultrasound is not recommended as an adjunct to clinical examination in differentiating between cellulitis and fluctuant swellings. The cost of adding an ultrasound machine to the dental practice greatly outweighs
the benefit. Further research should be done to investigate whether the treatment of cellulitis and fluctuance differs, evaluation of treatment (incision for drainage versus aspiration techniques), and other possible methodologies.
References


57. Siemens Acuson P50 Ultrasound System User Guide.


### Table 1. Age, initial pain, and measurement data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
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<th>Upper 95% CL</th>
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<td>13.6</td>
<td>34.2</td>
<td>40.2</td>
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<td>100</td>
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<td>12.8</td>
<td>3.4</td>
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<td>6.6</td>
<td>18.1</td>
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<tr>
<td>Height****</td>
<td>47</td>
<td>6.5</td>
<td>3.2</td>
<td>5.6</td>
<td>7.4</td>
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* Using Heft Parker Visual Analog Scale.

** Depth of central swelling measured from surface of skin.

** Width of purulence pocket if suspected.

*** Height of purulence pocket if suspected.

### Table 2. Preoperative Variables for all subjects.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
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<tr>
<td><strong>Jaw</strong></td>
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<td>Maxilla</td>
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<td>Mandible</td>
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<td><strong>Side</strong></td>
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<td>Left</td>
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<td>Right</td>
<td>44</td>
<td>53.7</td>
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<td><strong>Gender</strong></td>
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<td>Male</td>
<td>46</td>
<td>56.1</td>
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<td><strong>Antibiotics</strong></td>
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<td>37.0</td>
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<td>17.1</td>
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<td>Maxillary Posterior</td>
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<td>29.3</td>
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<tr>
<td>Mandibular Anterior</td>
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<td>Mandibular Posterior</td>
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<td>50.0</td>
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N = 82 for jaw, side, gender, and tooth type
N = 81 for antibiotics
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<tr>
<th>Variable</th>
<th>Frequency Cellulitis</th>
<th>Percent</th>
<th>Frequency Fluctuance</th>
<th>Percent</th>
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<tr>
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<td>16</td>
<td>53.3</td>
<td>30</td>
<td>57.7</td>
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Table 3. Tooth type and gender grouped by cellulitis and fluctuance.
N = 30 (Cellulitis)
N = 52 (Fluctuance)

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<thead>
<tr>
<th>Diagnosis</th>
<th>Clinical Exam Diagnosis</th>
<th>Ultrasound &amp; Clinical Exam Diagnosis</th>
<th>Findings after Incision for Drainage</th>
<th>Ultrasound Diagnosis Alone</th>
<th>Expert Ultrasound Diagnosis Alone</th>
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<tr>
<td>Cellulitis</td>
<td>14</td>
<td>19</td>
<td>30</td>
<td>22</td>
<td>29</td>
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<tr>
<td>%</td>
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<td>23.2</td>
<td>36.6</td>
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<tr>
<td>Fluctuant</td>
<td>68</td>
<td>63</td>
<td>52</td>
<td>59</td>
<td>52</td>
</tr>
<tr>
<td>%</td>
<td>82.9</td>
<td>76.8</td>
<td>63.4</td>
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<td>82</td>
<td>81</td>
<td>79</td>
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Table 4. Diagnoses after clinical exam, clinical and ultrasound exam, incision for drainage, ultrasound exam alone and expert ultrasound exam alone.
<table>
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<th>Percent</th>
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<td></td>
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<tr>
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<td>26</td>
<td>31.7</td>
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<tr>
<td>Correct</td>
<td>56</td>
<td>68.3</td>
</tr>
<tr>
<td>Clinical and Ultrasound</td>
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<td></td>
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<tr>
<td>Incorrect</td>
<td>25</td>
<td>30.5</td>
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<tr>
<td>Correct</td>
<td>57</td>
<td>69.5</td>
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</tbody>
</table>

Table 5. Clinical exam alone versus clinical exam plus ultrasound correct and incorrect diagnoses.

N = 82
* Analyzed using the McNemar test.

p-value* 0.7815
<table>
<thead>
<tr>
<th></th>
<th>Clinical Exam Diagnosis</th>
<th>Ultrasound &amp; Clinical Exam Diagnosis</th>
<th>Ultrasound Diagnosis Alone</th>
<th>Expert Ultrasound Diagnosis Alone</th>
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<tr>
<td>True Positive</td>
<td>9</td>
<td>12</td>
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<tr>
<td>True Negative</td>
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<td>False Negative</td>
<td>21</td>
<td>18</td>
<td>19</td>
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<tr>
<td>Sensitivity</td>
<td>30.0</td>
<td>40.0</td>
<td>34.5</td>
<td>55.2</td>
</tr>
<tr>
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<td>14.7</td>
<td>22.7</td>
<td>17.9</td>
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<tr>
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<td>49.4</td>
<td>59.4</td>
<td>54.3</td>
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<tr>
<td>Specificity</td>
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<td>86.5</td>
<td>76.9</td>
<td>75.0</td>
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<tr>
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<td>79.0</td>
<td>74.2</td>
<td>63.2</td>
<td>61.1</td>
</tr>
<tr>
<td>UCB</td>
<td>96.8</td>
<td>94.4</td>
<td>87.5</td>
<td>86.0</td>
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<tr>
<td>Positive Predictive Value</td>
<td>64.3</td>
<td>63.2</td>
<td>45.5</td>
<td>55.2</td>
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<td>38.4</td>
<td>34.4</td>
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<td>UCB</td>
<td>87.2</td>
<td>83.7</td>
<td>67.8</td>
<td>73.6</td>
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<td>Negative Predictive Value</td>
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<td>71.4</td>
<td>67.8</td>
<td>75.0</td>
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<tr>
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<tr>
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<td>82.1</td>
<td>79.4</td>
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<tr>
<td>Accuracy</td>
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<td>61.7</td>
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<td>72.3</td>
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<td>14.8</td>
<td>16.0</td>
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<td>3.5</td>
<td>7.9</td>
<td>8.8</td>
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<tr>
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<tr>
<td>False Negatives</td>
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<td>23.5</td>
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<tr>
<td>UCB</td>
<td>36.4</td>
<td>32.5</td>
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<td>25.9</td>
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Table 6. Statistical analysis of diagnoses.

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<th>Evaluator</th>
<th>N</th>
<th>Agree</th>
<th>% Agree</th>
<th>K</th>
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<th>UCB 95</th>
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<td>75</td>
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<td>0.81</td>
<td>0.66</td>
<td>0.95</td>
<td>0.0000*</td>
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<td>Expert</td>
<td>81</td>
<td>59</td>
<td>72.8</td>
<td>0.32</td>
<td>0.12</td>
<td>0.51</td>
<td>0.0012*</td>
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</table>

Table 7. Operator and expert reliability for ultrasonic diagnosis.
* Values analyzed using the reliability coefficient.
APPENDIX B

FIGURES
Figure 1. Sensitivity with 95% confidence intervals.

Figure 2. Specificity with 95% confidence intervals.
Figure 3. Positive predictive value with 95% confidence intervals.

Figure 4. Negative predictive value with 95% confidence intervals.
Figure 5. Accuracy with 95% confidence intervals.
Figure 6: Ultrasound image of a cellulitis (cobblestoning).

Figure 7: Ultrasound image of a cellulitis (cobblestoning). Squire et al.
Figure 8: Ultrasound image of a fluctuance (anechoic area above bone).

Figure 9: Ultrasound image of a fluctuance. Squire et al.
Figure 10: Ultrasound image with Power Doppler.

Figure 11: Ultrasound image with Color Doppler.
APPENDIX C

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

Study Title: A prospective study of emergency patients with facial swelling and toothache: a two part investigation. PART ONE

Principal Investigator: Dr. Melissa Drum

Sponsor: Not applicable

• 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 compare the accuracy of clinical examination plus the use of an ultrasound unit versus clinical examination in the diagnosis of facial swellings in patients experiencing pain.

2. How many people will take part in this study?

Ninety (90) 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 also swelling of the face. You are aware that the tooth and the swelling need treatment. If you decide to participate in this study, you will be required to complete a medical history questionnaire. If you are a female and are pregnant or nursing, you will not be able to participate. If you are a woman able to have children, you will be required to take a urine pregnancy test before participation.

Your tooth will be tested to insure an accurate diagnosis. It will first be tested with a cold cotton pellet chilled with an ice spray and then a device called an electric pulp tester. The electric pulp tester is a battery operated device that delivers a very small amount of current to the tooth resulting in a tingling sensation that might be uncomfortable or cause pain in the tooth being tested and which may last up to one second. Both tests are used routinely in diagnosis and are the standard of care. Your temperature will also be taken. You will be required to complete a questionnaire on your level of anxiety (nervousness). Then, you will be asked to rate the level of pain you are having prior to any treatment.

Your swelling will be examined first by touch both inside and outside of the mouth and a tentative diagnosis will be recorded by the doctor. The same swelling will then be evaluated using an ultrasound unit that is rubbed on the outside of the face and a tentative diagnosis will be recorded by the doctor. This procedure is for research purposes. You will be examined and treated if you do not participate in the study. The only difference is if you participate in the study, we will use an ultrasound to image your swelling.

Following an injection(s) (shot) of numbing solution, an incision (cut) will be made into the swelling on the inside of your mouth. Dissection (gentle pushing and exploring) of the swelling will be done and drainage of pus or no pus will be recorded. You will be asked to rate the amount of pain you feel during the incision and dissection phases. This is a dental procedure that is routinely done in swollen patients.

4. **How long will I be in the study?**

You will have one appointment, which will last approximately 60 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 or soreness associated with the incision (cut) or injection (shot) sites for a few days. Bruising or bleeding may also occur. You may develop additional swelling or an infection at the incision (cut) site. An altered sensation of your lip or tongue that may last up to a few weeks is also an infrequent side effect.

In addition, a risk of breach of confidentiality is possible in which sensitive medical information may be viewed by someone not involved with this research study. We take many precautions, including using a code number instead of your name, to prevent this from happening.

7. **What benefits can I expect from being in the study?**

*You may not directly benefit from this study. The use of ultrasound may help localize the area of infection.*

8. **What other choices do I have if I do not take part in the study?**

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?**

The study will pay for the cost of the urine pregnancy test and the ultrasound test.

11. **Will I be paid for taking part in this study?**
Yes, you will be paid $75 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. Lisa Leone 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. Lisa Poweski 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>Date and time</td>
<td></td>
<td></td>
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</tbody>
</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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<td>Date and time</td>
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<table>
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<th>AM/PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date and time</td>
<td></td>
</tr>
</tbody>
</table>

**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>
<thead>
<tr>
<th>Printed name of person obtaining consent</th>
<th>Signature of person obtaining consent</th>
<th>AM/PM</th>
</tr>
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<tr>
<td>Date and time</td>
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**Witness(es) - May be left blank if not required by the IRB**

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<thead>
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<tbody>
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<table>
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APPENDIX D

PATIENT PRIVACY FORM
THE OHIO STATE UNIVERSITY

AUTHORIZATION TO USE

PERSONAL HEALTH INFORMATION IN RESEARCH

Title of the Study: A prospective study of emergency patients with facial swelling and toothache: a two part investigation.

OSU Protocol Number:

Principal Investigator: Dr. Melissa Drum

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: _______________

Page 1 of 3

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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. Other Ohio State University staff not involved in the study but who may become involved in your care for study-related treatment will have access to your information.

- 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 Human 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 43218 or Dr. Stanley Vermilyea at the College of Dentistry, 305 w 12th avenue, the Ohio State University, Columbus, Ohio 43218.

- 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. Stanley Vermilyea at the College of Dentistry, 305 w 12th avenue, the Ohio State University, Columbus, Ohio 43218.
- 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 43218.
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 E

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__________
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>
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<th>Reason</th>
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</table>

**Summary of Patient’s Medical Status:**

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

**Medical Risk Assessment**

- □ ASA I (healthy individual)
- □ ASA II (mild systemic disease)
- □ ASA III (severe disease but not incapacitating)
- □ 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 F

CORAH’S DENTAL ANXIETY QUESTIONNAIRE
Pre-Injection Questionnaire

PLEASE ANSWER THE FOLLOWING QUESTIONS BY CIRCLING THE
ANSWER THAT BEST DESCRIBES 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 afraid 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 in a sweat or almost feel physically sick.

3. When you are in the dentist's chair waiting while she/he gets her/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 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 she/he will use to scrape your
   teeth around your gums, how do you feel?
   a) Relaxed.
   b) A little uneasy.
   c) Tense.
   d) Anxious.
   e) So anxious that I sometimes break in a sweat or almost feel physically sick.
APPENDIX G
INITIAL PAIN RATING
Initial Pain Rating

Code #: __________

1. Please place an “X” on the line below to rank the level of pain that brought you here today.

<table>
<thead>
<tr>
<th>None</th>
<th>Faint</th>
<th>Weak</th>
<th>Mild</th>
<th>Moderate</th>
<th>Strong</th>
<th>Intense</th>
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Note: Not to scale. For representation purposes only
• 0-54 mm………..Mild pain
• 55-113 mm……..Moderate pain
• 114 -170 mm……..Severe pain