“For I seek the truth by which no man has ever been harmed.”
–Marcus Aurelius, Meditations VI. 21, 173 AD

Before initiating treatment, one must first assemble collective information regarding signs, symptoms, and history. That information is then combined with results from the clinical examination and tests. This process is diagnosis. Stated another way, diagnosis is the procedure of accepting a patient, recognizing that he has a problem, determining the cause of the problem, and developing a treatment plan that will solve or alleviate the problem.

The diagnostician must have a thorough knowledge of examination procedures—percussion, palpation, probing, and pulp testing; a knowledge of pathosis and its radiographic and clinical manifestations; an awareness of the various modalities of treatment; and, above all, a questioning mind. To be added to these critical skills is the most basic skill of all, listening to the patient.

Of all of the important diagnostic tools, the art of listening is the most underrated. Yet careful and attentive listening establishes patient-dentist rapport, understanding, and trust. Such a relationship also enhances the patient’s reliability as a historian.1

REQUIREMENTS OF A DIAGNOSTICIAN
Diagnosis is a personal and cognitive experience; therefore, many of the qualities of a good diagnostician are of an interpersonal nature and are based on knowledge, experience, and diagnostic tools. Diagnosing orofacial disease is similar to other medical diagnosis. Pulp tests, radiographs, percussion, palpation, and other tests and procedures can facilitate the diagnosing of dental/facial disease, just as the electrocardiograph, electroencephalograph, echocardiograph, computed axial tomographic and magnetic resonance imaging scan, and a host of other radiographs can facilitate medical diagnosis.

A dentist can develop a number of assets to become a successful diagnostician. The most important of these are knowledge, interest, intuition, curiosity, and patience. The successful diagnostician must also have acute senses and the necessary equipment for diagnosis.

Knowledge
Primarily, a dentist must depend on himself, not the laboratory. Therefore, knowledge is the most important asset the dentist must possess. This includes familiarity with all local orofacial causes of pain, as well as numerous systemic, neurogenic, and psychological causes. In addition, the dentist must be aware of the many physical, perceptual, emotional, and behavioral changes brought about by chronic pain. He must know that constant overwhelming pain can affect the function of every organ of the body. Chronic pain patients can develop increased blood pressure, heart rate, kidney function, decreased bowel activity, and hormone levels. They can have many symptoms, such as nausea, vomiting, photophobia, tinnitus, and vertigo. The astute clinician gathers knowledge about the patient and his problem through a thorough history and an examination. The history and examination include evaluating the physical, emotional, behavioral, and perceptual aspects of the patient’s pain experience.

Under knowledge must also be listed the important asset of knowing when and where to refer the patient for additional consultation. This comes with experience and the help of physicians, psychologists, and fellow dentists who may be depended on to assist in diagnosis. Often the patient is referred because examination reveals a problem clearly in the province of the neurologist or otolaryngologist. Sometimes the patient is referred because the examiner has exhausted his knowledge and needs help in diagnosis. The recognition of fallibility and limitation—knowing when to yell for help—is also a major asset to the dentist.
Interest
The second important asset possessed by a good diagnostician is interest. The dentist must have a keen interest in the patient and his or her problem and must evidence this interest by handling the patient with understanding. If this attitude is not natural to the dentist, he will render the patient and the profession a service by referring all diagnostic problems to an interested and competent fellow practitioner.

Intuition
In addition to interest and knowledge, the good diagnostician is blessed with intuition or "sixth sense," so to speak. Good diagnosticians intuitively sense the presence of something unusual. This ability, which sometimes allows for "instant" diagnosis, is developed through broad experience with pain problems having unusual and multiple diagnoses.

Intuition tells the dentist when the patient is holding back information or is not telling the complete truth. Moreover, intuition immediately makes the examiner subtly aware of the patient who "knows too much," that is, all of the words and symptoms related to a certain condition. Intuition allows the dentist to suspect the unusual, but it also goes hand in hand with still another prime asset of a good diagnostician, curiosity.

Curiosity
The dentist must pursue or develop a natural curiosity about the patient and his condition if perseverance is to be maintained in arriving at a diagnosis. Dr. Harry Sicher often likened dental diagnosis to the actions of a good detective, and curiosity is a detective's greatest asset (personal communication, 1954). Medawar described diagnosis as the "use of the hypothetico-deductive system." Again, curiosity goes with interest, and the dentist who is bored by the painstaking methods of diagnosis will never have the curiosity to delve a little deeper, probe a little further, or ask the unusual. All of this takes time and thus requires patience.

Patience
Often a definitive diagnosis of unusual pain may take hours, days, or even months to develop. Some patients complaining of unusual pain may have suffered this pain for years, so the dentist cannot expect to make a quick diagnosis in a matter of minutes. This is the reason, as stated earlier, why a difficult diagnosis may be unrewarding financially but very rewarding emotionally. Again, if the dentist is not willing to sacrifice the time to attempt to help these individuals, he is urged to refer the patient for diagnosis rather than make an incorrect, quick diagnosis that may result in improper treatment, such as reaching for the forceps or removing a healthy pulp.

The dentist obviously cannot abandon other patients to see one person repeatedly. Too frequently, the problem patient is asked to return at the end of the day, when both dentist and patient are tired and irritable. A better solution is to see the patient in the morning, before office hours. The dentists who are not willing to assume this imposition, and they are many, are urged to refer the patient to their more altruistic colleagues.

Senses
The good diagnostician must have the astuteness to grasp what his senses reveal. First, he has a voice to ask questions and ears to hear the answer; he has eyes to see and hands to probe and palpate. In short, the dentist has senses with which to communicate with the sick patient. But, as Friedman pointed out, "One must learn to listen with the third ear and see with the third eye" (personal communication, 1972).

Controlling these senses, however, is the mind, and if the mind does not inquire and then reason, or has not accumulated the knowledge necessary to inquire and finally to analyze, then the senses are useless. The mind must list all of the possible causes of the pain and then, more often than not, eliminate them one by one until the correct diagnosis is made.

HISTORY
Anamnesis, "recollection" or "calling to memory," is the first step in developing a diagnosis. The importance of obtaining and recording this "history" goes beyond medicolegal protection. A complete history (Table 6-1) will not determine treatment but may influence modifications in endodontic treatment modalities. It will seldom deny treatment. A complete medical history should contain, as a baseline, the vital signs; give early warning of unsuspected general disease; and define risks to the health of the staff as well as identify the risks of treatment to the patient. The medical history must be updated regularly, especially if there have been any changes in the patient's health status.

The procedure developed by the American Society of Anesthesiologists is a good system for organizing and assigning risk (Table 6-2). Once the status of the patient's general health has been established, a dental diagnosis is best developed by following the time-honored formula of determining the chief complaint, enlarging on this complaint with questions about the present dental illness, relating the history of past dental illness to the chief complaint, and combining this
**Table 6-1 Medical History Form**

<table>
<thead>
<tr>
<th>MEDICAL HISTORY</th>
<th>CIRCLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Sex</td>
</tr>
<tr>
<td>Address</td>
<td></td>
</tr>
<tr>
<td>Telephone</td>
<td>Height</td>
</tr>
<tr>
<td>Date</td>
<td>Occupation</td>
</tr>
</tbody>
</table>

1. Are you having pain or discomfort at this time? ................................................................. YES NO
2. Do you feel very nervous about having dentistry treatment? .................................................... YES NO
3. Have you ever had a bad experience in the dentistry office? ..................................................... YES NO
4. Have you been a patient in the hospital during the past 2 years? ............................................. YES NO
5. Have you been under the care of a medical doctor during the past 2 years? .............................. YES NO
6. Have you taken any medicine or drugs during the past 2 years? .............................................. YES NO
7. Are you allergic to (ie, itching, rash, swelling of hands, feet, or eyes) or made sick by penicillin, aspirin, codeine, or any drugs or medications? ........................................... YES NO
8. Have you ever had any excessive bleeding requiring special treatment? .................................... YES NO
9. Circle any of the following which you have had or have at present:

- Heart Failure
- Heart Disease or Attack
- Angina Pectoris
- High Blood Pressure
- Heart Murmur
- Rheumatic Fever
- Congenital Heart Lesions
- Scarlet Fever
- Artificial Heart Valve
- Heart Pacemaker
- Heart Surgery
- Artificial Joint
- Anemia
- Stroke
- Kidney Trouble
- Ulcers

- Emphysema
- Cough
- Tuberculosis (TB)
- Asthma
- Hay Fever
- Sinus Trouble
- Allergies or Hives
- Diabetes
- Thyroid Disease
- X-ray or Cobalt Treatment
- Chemotherapy (Cancer, Leukemia)
- Arthritis
- Rheumatism
- Cortisone Medicine
- Glaucoma
- Pain in Jaw Joints

- AIDS or HIV
- Hepatitis A (infectious)
- Hepatitis B (serum)
- Liver Disease
- Yellow Jaundice
- Blood Transfusion
- Drug Addiction
- Hemophilia
- Venerable Disease (Syphilis, Gonorrhea)
- Cold Sores
- Genital Herpes
- Epilepsy or Seizures
- Fainting or Dizzy Spells
- Nervousness
- Psychiatric Treatment
- Sickle Cell Disease
- Bruise Easily

10. When you walk up stairs or take a walk, do you ever have to stop because of pain in your chest, or shortness of breath, or because you are very tired? ..................................................... YES NO
11. Do your ankles swell during the day? ....................................................................................... YES NO
12. Do you use more than two pillows to sleep? ............................................................................ YES NO
13. Have you lost or gained more than 10 pounds in the past year? ............................................. YES NO
14. Do you ever wake up from sleep short of breath? ................................................................... YES NO
15. Are you on a special diet? ......................................................................................................... YES NO
16. Has your medical doctor ever said you have a cancer or tumor? ............................................. YES NO
17. Do you have any disease, condition, or problem not listed? .................................................. YES NO
18. WOMEN: Are you pregnant now? ............................................................................................ YES NO
   Do you anticipate becoming pregnant? ......................................................................................... YES NO

To the best of my knowledge, all of the preceding answers are true and correct. If I ever have any change in my health, or if my medicines change, I will inform the doctor of dentistry at the next appointment without fail.

<table>
<thead>
<tr>
<th>Date</th>
<th>Dentist Signature</th>
<th>Signature of Patient, Parent, or Guardian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**MEDICAL HISTORY/PHYSICAL EVALUATION UPDATE**

<table>
<thead>
<tr>
<th>Date</th>
<th>Addition</th>
<th>Signatures</th>
</tr>
</thead>
<tbody>
<tr>
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This comprehensive medical history responds to contemporary advances in physical evaluation and to increasing malpractice claims.

with information about the patient’s general health (medical history) and the examination results.

Chief Complaint

The chief complaint, usually in the patient’s own words, is a description of the dental problem for which the patient seeks care. The verbal complaint may be accompanied by the patient pointing to the general area of the problem.

After establishment and recording of the chief complaint, the examination process is continued by obtaining a history of the present illness.

A patient in acute distress should undergo diagnosis and examination as quickly as possible so the chief complaint may be treated as expeditiously as possible. At a later time, when the patient is pain free and more rational, a complete treatment plan may be established. No treatment should be rendered unless the examiner is certain of the diagnosis. Patients with severe pain from pulpitis have difficulty in cooperating with the diagnostic procedures, but until the diagnosis has been made and the correct tooth identified, treatment must not be started (see chapter 7).

Present Dental Illness

A history of the present illness should indicate the severity and the urgency of the problem. If the problem is long-standing, proceed with detailed questions about past episodes of pain or swelling and any previous treatment performed to remedy the condition.

Pain is frequently the main component of the patient’s complaint. A history of pain that persists without exacerbation may indicate a problem not of dental origin. If the chief complaint is “toothache” but the symptoms are too vague to establish a diagnosis, analgesics can be prescribed to help the patient tolerate the pain until the toothache localizes. If the patient arrives self-medicated with analgesics or sedatives, a diagnosis may be difficult to establish.

The initial questions should help establish two basic components of pain: time (chronicity) and severity (or intensity). Start by asking such questions as “How long have you had this problem?” “How painful is it?” and “How often does it hurt?” Continue the questioning with “When does it hurt?” and “When does it go away?” “What makes it hurt?” “What makes it hurt worse?” and “What makes it hurt less or go away?”

A history of painful responses to thermal changes suggests a problem of pulpal origin and will need to be followed up with clinical tests, using the thermal test that would most closely duplicate the patient’s complaint: use ice if the complaint is pain with cold, and use a hot stimulus if the complaint is pain with such things as hot drinks. It could also be important to

<table>
<thead>
<tr>
<th>ASA Class</th>
<th>Patient Description</th>
<th>Clinical Examples</th>
<th>Clinical Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A normally healthy patient</td>
<td>No organic, physiologic, biochemical, or psychiatric disturbance; treatment is for localized disorder</td>
<td>Routine care</td>
</tr>
<tr>
<td>2</td>
<td>A patient with mild systemic disease</td>
<td>Controlled essential hypertension, pronounced obesity, psychiatric disturbance</td>
<td>Routine care but limit procedural stress and length of appointment</td>
</tr>
<tr>
<td>3</td>
<td>A patient with severe systemic disease that is not incapacitating</td>
<td>Severe diabetes mellitus, congestive heart failure, chronic obstructive pulmonary disease</td>
<td>Strict limitation of complex procedures; careful anxiety control</td>
</tr>
<tr>
<td>4</td>
<td>A patient with an incapacitating systemic disease that is a constant threat to life</td>
<td>Acute myocardial infarction; advanced pulmonary, cardiac, hepatic, or renal insufficiency</td>
<td>Emergency or palliative care, usually in a hospital</td>
</tr>
<tr>
<td>5</td>
<td>A moribund patient who is not expected to live 24 hours with or without operation</td>
<td>Uncontrolled massive internal bleeding, rapidly progressing cardiac insufficiency with renal failure</td>
<td>Emergency life support only</td>
</tr>
</tbody>
</table>

*Used to categorize patients following history and examination. Classification should be entered prominently in chart. Assigning risk from treatment and level of clinical management follows classification. American Society of Anesthesiologists. New classification of physical status. Anesthesiology 1963;24:111.
learn that a tooth has been sensitive to thermal changes but no longer responds to such stimuli; this would indicate that the tooth may have a pulp that is now necrotic.\textsuperscript{5}

A history of painful response to eating and biting or pain on pressing the gingiva is also helpful. Minor sensitivities or swellings, very noticeable to the patient, can initially be overlooked by the examiner. These may prove to be very important diagnostic clues and should be noted. A collection of data such as that shown in Figure 6-1 is helpful in directing the examination procedures and sometimes in pinpointing the problem.

The type and number of past dental treatments should reveal the degree of sophistication of previous therapy and help in evaluating the expectations of the patient as well. The presence of obvious dental neglect or the unwillingness of the patient to have a pulpless tooth restored may rule out endodontic therapy.

The question, “What kind of treatment have you had?” might elicit a history of pulp capping, deep fillings with sedative bases, or indirect pulp caps. These teeth, as well as those that have received impact trauma, may exhibit calcific metamorphosis or dystrophic calcifications and may be a difficult endodontic treatment.

Figure 6-1  A, Chief complaint of vague discomfort directed attention to an incomplete root canal filling. However, the examination was redirected to calculus and periodontal disease, when it was revealed that the treatment was 50 years old. B, Radiograph taken immediately after filling suggests gross overfill (arrow). C, An occlusal radiograph, however, shows a sialolith, that was not initially suspected (arrow). Repeated surgery for this condition had not been elicited in the past dental history. Reproduced from Marshall FJ. Dent Clin North Am 1979;23:495.
problem (Figure 6-2). Although a positive and accurate answer may not result, the question will prompt a closer look at radiographs for the presence or absence of cement bases or for recurrent caries or caries remaining under restorations (Figure 6-3).

Full-crown restorations should also raise questions to the patient regarding “wet” or “dry” drilling. “Dry drilling” may result in an increased incidence of inflammation and even internal resorption (see Figure 4-44). Patients who have undergone orthodontic treatment may have areas of resorption or pulpal changes. In the past decade, there has been an increased interest in adult orthodontics, and recent studies indicate that the adult pulp may be more susceptible than younger pulps to such iatral trauma⁶ (Figure 6-4).

The question, “How many times has this tooth or have these teeth been treated?” is also pertinent. A tooth with a history of repeated restorations and multiple occurrences of caries (“stressed pulp”) should be evaluated carefully with respect to pulpal status before procedures such as full crowns or bridge abutment restorations are initiated. Root canal therapy prior to restorations in such teeth is often indicated. The question, “How recently has this tooth or area been treated?” may provide information that the problem of thermal sensitivity is merely a reaction to a recently placed restoration. If the pain is of low intensity, a patient may tolerate it in the hope that it will subside. Pain existing for several months may have become part of the patient’s lifestyle.⁷

A history of long-standing, severe pain should raise suspicion that the condition may be other than pulpal in origin. Additional examinations for myofascial or neurologic pain, as well as cardiac referred pain or possibly psychogenic pain, should be considered. A more detailed discussion of this subject is found in chapter 8.

Finally, the patient must be asked about past reactions to dental procedures; to pain, both dental and general; and to expectations for treatment. A patient with a history of low pain threshold and strong analgesic dependency, as well as many previous attempts to solve the problem, may require special treatment or referral.

It should be noted that history taking is a process of questions and answers and that many questions are
repeated. These repeated questions are not redundant but are deliberate attempts to confirm data and validate the diagnosis.

Medical History
Patients need to share their medical problems with their dentists so the data can be used in planning treatment.8 This begins when the patient completes some standard form (see Table 6-1 or 6-2), usually at the same time as the receptionist records other basic data. The confidence needed to share these data builds slowly in some people. Thus, there is a need to review carefully and sincerely the answers the patient has recorded on the health history form. This review may be more comfortable for the patient after asking about the chief complaint.

In reviewing the medical history, particular emphasis must be placed on illnesses, history of bleeding, and medications. Illness often means hospitalization to patients; consequently, they may not list weight changes, accidents, or problems related to stress and tension. Patients who are African American should be questioned about sickle cell anemia; there is a report of pulp necrosis occurring in patients with this distressing condition.9

The term bleeding is usually interpreted by the patient to mean frank blood and seldom elicits answers related to bruising or healing time, chronic use of aspirin10 (not considered a drug by many people), or a history of liver disease. These should all be specifically mentioned in the medical history form.

Medication means to many people only those items obtained by written prescription. Dentists must also ask about “pills” and “drugs.” With the availability of home remedy “medical” texts, many people are self-medicating with diet pills, sleep inducers, and vitamins, as well as “recreational drugs,” to mention only a few. Even if these self-administered medications do not influence treatment directly, the knowledge that patients have a tendency to “do their own thing” may be helpful in planning treatment.

Women should be asked if they are pregnant or if they have menstrual or menopausal problems. Positive answers to these questions must be weighed and evaluated along with the other responses to determine the risk of treatment against the risk of nontreatment.

When the history uncovers a serious problem, and a review of the systems involved (cardiac, respiratory, etc) does not explain the problem, the patient’s physician must be consulted.

During these interviews, the dentist-patient relationship tends to crystallize. A rapport is established that is relevant and meaningful to all future relationships. This is the time when anxious, frightened patients may be calmed and reassured even though they may not be completely at ease until the first treatment is completed and they learn that dental procedures can be uneventful and nontraumatic.

Kindness and attention to their concerns or problems (chief complaint) during the history-taking will greatly reduce most patients’ emotional trauma and stress, particularly when this phase is followed by a thorough, painless examination.

CLINICAL EXAMINATION
In general, the clinical examination should follow a logical sequence from the general to the specific, from the more obvious to the less obvious, from the external to the internal. The results of the examination, along with the information from the patient’s history, will be combined to establish the diagnosis, formulate a treatment plan, and determine the prognosis.

Vital Signs
The first step in examination is to record the patient’s vital signs, thus establishing a baseline or a “norm” for each patient during treatment, whether routine or emergency. Patients with test values outside the range of acceptable norms are at risk, as is the dentist who treats them.8 Common sense suggests that this risk should be shared with the patient’s physician by a telephone conversation at least. Information received should be recorded in the chart and dated.
The vital signs may be recorded by any trained member of the office team. However, abnormal values must be evaluated by the doctor. The person of first contact should also record, for later evaluation, any additional observations of abnormalities such as breathlessness, color change, altered gait, or unusual body movements observed during the initial meeting.

**Blood Pressure** (normal: 120/80 mm Hg for persons under age 60; 140/90 mm Hg for persons over age 60). Routine use of the sphygmomanometer not only establishes a baseline blood pressure but occasionally brings to light unsuspected cases of hypertension in patients who are not regularly seeing a physician or are not maintaining prescribed regimens of therapy. Halpern reported that only 18% of the dental clinic patients attending Temple University Dental School "were seeing their physicians." At times, however, elevated blood pressure is caused only by the stress and anxiety of the moment and can be dealt with by reassurance or, if necessary, pretreatment sedation. Even more important, however, is the emphasis that this face-to-face procedure places on an examination. Both the patient and the doctor are inclined to be more serious in their questions and answers when the examination begins with blood pressure records. It must be stressed that no patient, with or without a dental emergency, should be treated when his diastolic blood pressure is over 100 mm.

**Pulse Rate and Respiration** (normal: pulse, 60 to 100 beats/minute; respiration, 16 to 18 breaths per minute). When these examinations are added to the recording of blood pressure, the dentist increases the opportunity to know the patient better. These examinations also show the patient, by physical contact, how further examination will proceed—deliberately, gently, and completely. Pulse and respiration rates may also be elevated owing to stress and anxiety; in fact, these signs may be even better indicators of stress than is blood pressure. Tests with markedly positive findings should be repeated later in the appointment or at a subsequent appointment.

**Temperature** (normal: body temperature, 98.6 °F [37°C]). The taking and recording of body temperature is a simple, significant procedure. An elevated temperature (fever) is one indication of a total body reaction to inflammatory disease. If the body temperature is not elevated, one can assume that the body is "managing" its defenses well, that whatever the local signs are (pain, swelling, abscess formation, etc), systemic treatment, with its attendant risks, will likely not be required. A temperature above 98.6°F but less than 100°F indicates localized disease. Localized disease can usually be treated by removing the cause (eg, cleaning the root canal) and/or incision and drainage.

**Cancer Screen** (soft tissue examination: lumps, bumps, white spots). Every new patient must be routinely screened for cancer and other soft tissue nonodontogenic conditions as part of the examination. And they must be informed of the results! This examination should include a survey of the face, lips, neck, and intraoral soft tissues. When such examinations are made routinely, without secrecy, they will usually dispel the unstated fears of the cancerphobe and add to the confidence and rapport of all patients with their dentists. The sooner this examination is completed the better.

It is sometimes argued that dentists are liable if they inform patients that they are performing an examination and then miss finding disease when it is present. In fact, dentists are even more liable if they miss reporting the disease because they have not made an examination.

Extraorally, a cancer survey includes palpation for masses and examination for asymmetry and color changes. Intraorally, this examination is repeated with the additional care of directed lighting and of moving the tongue in such a manner so that all areas can be clearly seen (Table 6-3). Detailed procedures are presented elsewhere.

### Extraoral Examination

Inflammatory changes originating intraorally and observable extraorally may indicate a serious, spreading problem. The patient must be examined for asymmetries, localized swelling, changes in color or bruises, abrasions, cuts or scars, and similar signs of disease, trauma, or previous treatment. Positive findings combined with the chief complaint and information about past injuries or previous treatments to teeth or jaws will begin to clarify the extent of the patient’s problem.

The extraoral examination includes the face, lips, and neck, which may need to be palpated if the patient reports soreness or if there are apparent areas of inflammation. Painful and/or enlarged lymph nodes are of particular importance. They denote the spread of

<table>
<thead>
<tr>
<th>Table 6-3 Oral Cancer Warning Signals*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swelling, lump, or growth anywhere in or about the mouth</td>
</tr>
<tr>
<td>White, scaly patches inside the mouth</td>
</tr>
<tr>
<td>Any sore that does not heal</td>
</tr>
<tr>
<td>Numbness or pain anywhere in the mouth area</td>
</tr>
<tr>
<td>Repeated bleeding in the mouth without cause</td>
</tr>
</tbody>
</table>

*“Open Wide,” Reproduced with permission from the American Cancer Society, New York.
inflammation as well as possible malignant disease. The extent and manner of jaw opening can provide information about possible myofascial pain and dysfunction. The temporomandibular joint should be examined during function for sensitivity to palpation, joint noise, and irregular movement.

Intraoral Examination
The intraoral examination is begun with a general evaluation of the oral structures. The lips and cheeks are retracted while the teeth are in occlusal contact and the oral vestibules and buccal mucosa are examined for localized swelling and sinus tract or color changes. With the patient's jaws apart, the dentist should evaluate in a similar manner the lingual and palatal soft tissues. Also, the presence of tori should be noted. Finally, as part of the general inspection, carious lesions, discolorations, and other obvious abnormalities associated with the teeth, including loss of teeth and presence of supernumerary or retained deciduous teeth, should be noted.

Often the particular tooth causing the complaint is readily noted during this visual examination if it has not already been pointed out by the patient. Complaints associated with discolored or fractured teeth, teeth with gross caries or large restorations, and teeth restored by full coverage are for the most part readily located. True “puzzlement” begins when the complaint centers on teeth fully crowned and part of extensive bridges or splints, or when only a few teeth are restored, and then only with minimal restorations.

Transillumination with a fiber-optic light, directed through the crowns of teeth, can add further information. By this method, a pulpless tooth that is not noticeably discolored may show a gross difference in translucency when the shadow produced on a mirror is compared to that of adjacent teeth. Transillumination may also locate teeth with vertical cracks or fractures.

If the involved tooth is not readily identified, it may be necessary to thoroughly examine all of the teeth in the half arch or opposing arch, depending on how specifically the patient can localize the area of pain. Although the size of a carious lesion or the presence of a crown or large restoration may point to the involved tooth, the symptoms may be referred pain or pain from an adjoining tooth with problems. Adjacent teeth with large restorations or crowns can be assumed to be equally at risk. Regardless of the presence or absence of findings, the patient's premonitions and descriptions should not be ignored in favor of what appears to be obvious. For the record and for the possibility of additional later treatment, the condition of all teeth in the immediate vicinity should also be recorded. This is especially true following an accident. In fact, the general state and care of the entire mouth must be noted along with the particular tooth’s restorability and strategic importance.

If the patient's chief complaint includes symptoms that occur following specific events (e.g., chewing, drinking cold liquids), the specific intraoral examination should include tests that duplicate or reproduce these symptoms. For example, if the chief complaint is pain with hot liquids, the clinical tests may include testing the suspected tooth with a hot stimulus. A positive response (development of the chief complaint) will be important evidence in establishing the diagnosis.

In the following sections, various tests will be described, detailing how to perform them and how to evaluate the results. The correct diagnosis can be established more readily the more information that is developed from all sources: history, clinical examination, radiographic evaluation, and clinical tests.

Coronal Evaluation. For psychological reasons and to expedite treatment, the most obviously affected tooth is examined first, particularly when the patient, the history, or the general examination calls attention to a certain tooth.

Using a mouth mirror and an explorer, and possibly a fiber-optic light source, the dentist carefully and thoroughly examines the suspected tooth or teeth for caries, defective restorations, discoloration, enamel loss, or defects that allow direct passage of stimuli to the pulp. Sometimes sealing off such leakage with temporary cements or periodontal dressings can be diagnostic (Figure 6-5). Vertical and horizontal fractures located by transillumination should be further investigated by hav-

Figure 6-5 Zinc oxide–eugenol temporary cement packed buccally and lingually to seal margins of a porcelain-fused-to-metal crown against external stimulus (leakage). If the patient’s complaint stops, then the margins can be permanently sealed or the crown remade. (Courtesy of Dr. F. James Marshall.)
ing the patient bite on some firm object such as the Tooth Slooth (Laguna Niguel, Calif.), or a wet cotton roll.\textsuperscript{18} Occlusal wear facets and parafunctional patterns are also sought out, as is tooth mobility.

**Pulpal Evaluation**

The clinical condition of the pulp can be evaluated by thermal stimuli, percussion, palpation, and vitality tests. Generally, pain of endodontic origin results from pulp inflammation that spreads from the coronal pulp apically to the periodontal ligament, which then spreads to the periosteum overlying the apical bone and beyond. Pulpal and periradicular symptoms, therefore, sometimes combine, making pulpal assessment difficult.

The purpose of evaluating the pulpal condition is to arrive at a diagnosis—namely, the nature of the disease involving the pulp. After determining the diagnosis, there are specific treatment options for each pulpal condition. Irreversible pulpitis and pulp necrosis require removal of the pulp (pulp extirpation and root canal treatment, or extraction of the tooth), whereas a tooth with a normal pulp or with reversible pulpitis may be treated by preserving the pulp (vital pulp therapy). The various methods of pulpal evaluation, then, do not dictate treatment but provide information that can be used with other information (history and radiographs) to establish a diagnosis. Pulp tests alone are usually not adequate for establishing a diagnosis but can provide very useful information.\textsuperscript{19,20}

**Clinical Endodontic Tests**

There are several ways to obtain information about the condition of a tooth's pulp and supporting structures. Probably no one test is sufficient in itself; the results of several tests often have to be obtained to have enough information to support a likely diagnosis or perhaps a list of differential diagnoses.

**Thermal Tests.** Two types of thermal tests are available, cold and hot stimuli. Neither is totally reliable in all cases, but both can provide very useful information in many cases of pulpal involvement.

The cold test may be used in differentiating between reversible and irreversible pulpitis and in identifying teeth with necrotic pulps. It can also alleviate pain brought on by hot or warm stimuli, a finding that patients sometimes discover can provide them with much relief.

When cold is used to differentiate between reversible and irreversible pulpitis, one must try to determine if the effect of stimulus application produces a lingering effect or if the pain subsides immediately on removal of the stimulus from the tooth. The "lingering" quality of pain to a cold stimulus might be considered in cases in which the patient clearly feels that the pain is still present several seconds after stimulus removal. In testing, if the pain lingers, that is taken as evidence for irreversible pulpitis; if pain subsides immediately after stimulus removal, hypersensitivity or reversible pulpitis is the more likely diagnosis.

Cold as a test for pulp vitality (pulp necrosis versus vital pulp) is probably not entirely reliable since teeth with calcified pulp spaces may have vital pulps, but cold stimuli may not be able to excite the nerve endings owing to the insulating effect of tertiary/irritation dentin.

Cold testing can be made with an air blast, a cold drink, an ice stick, ethyl chloride or Fluori-Methane (Gebauer Chemical Co., Cleveland, Ohio) sprayed on a cotton swab, or a carbon dioxide (CO\textsubscript{2}) dry "ice" stick.\textsuperscript{21} Fuss et al. found CO\textsubscript{2} "snow" or Fluori-Methane more reliable than ethyl chloride or an ice stick.\textsuperscript{22} Rickoff et al. reported that CO\textsubscript{2} snow applied to a tooth for as long as 5 minutes did not jeopardize the health of the pulp,\textsuperscript{23} nor does it damage the surface of the enamel.\textsuperscript{24} On the other hand, CO\textsubscript{2} does cause "pitting" of the surface when applied to porcelain on porcelain-fused-to-metal restorations for as little as 5.4 seconds.\textsuperscript{25}

The CO\textsubscript{2} dry ice stick is preferred for testing because it does not affect adjacent teeth, whereas the air blast and the ice stick do, and because it gives an intense, reproducible response\textsuperscript{26} (Figure 6-6). This has been confirmed by Peters et al. in their studies on the effects of CO\textsubscript{2} used as a pulpal test.\textsuperscript{24,27–29} Small icicles can be made in the office by freezing water in anesthetic needle covers.

When testing with a cold stimulus, one must begin with the most posterior tooth and advance toward the anterior teeth. Such a sequence will prevent melting ice water from dripping in a posterior direction and possibly excite a tooth not yet tested, giving a false response.

Hot testing can be made with a stick of heated gutta-percha or hot water. Both have advantages, but hot water may be preferable because it allows simulation of the clinical situation and also may be more effective in penetrating porcelain-fused-to-metal crowns.\textsuperscript{30}

The use of a hot stimulus in the form of hot water can help locate a symptomatic tooth with a necrotic (or dying) pulp. The effect tends to be lingering, and the main reason for using the test is to localize which tooth is symptomatic. Often other evidence (patient's own opinion, radiographs, history, clinical appearance) will indicate which tooth is suspected. This tooth is then **isolated with a rubber dam** so the hot water will flow only around the tooth. A positive response of pain, similar to the chief complaint, provides the information needed to identify the problem tooth.
For routine heat testing, gutta-percha, preferably baseplate gutta-percha, is warmed, formed into a cone, applied to a warmed instrument, reheated, and applied to the moistened tooth (so it will not adhere.) It is reheated for each tooth. If the patient is complaining of a severe toothache, one must be ready to apply cold immediately following a dramatic response to heat. The diagnosis is made!

Thermal testing, hot or cold, can be used for testing teeth with full coverage, to differentiate between vital and necrotic pulps, and requires only a “yes” or “no” response: is the stimulus perceived or not?  

**Percussion.** Apical periodontitis is usually an extension of pulpal inflammation, but it may also result from impact trauma, traumatic occlusion, or sinusitis affecting maxillary teeth. However, since apical periodontitis is so frequently associated with pulpal inflammation, percussion tests are included when evaluating pulpal conditions even though the percussion produces a response in the periodontium rather than the pulp.

The procedure for testing is simple: use a mirror handle and very gently tap the occlusal/incisal surfaces of several teeth in the area in question. Sometimes a tooth is so painful that merely touching it with a fingertip produces pain, so careful evaluation, prior to testing, is important.

The difficulty in evaluating percussive responses is one of quantity and quality. Does the pain signal inflammation with abscess formation, or is it just mild inflammation from an inflamed pulp? It has been stated that the percussive sound offers clues: a dull note signifies abscess formation, a sharp note merely inflammation. It is probably doubtful that such differentiation can be made consistently. Perhaps the most useful information from percussion is to identify which tooth may be the problem tooth, whereas the final diagnosis requires additional information.

**Palpation.** Sensitivity to finger pressure (palpation) on the mucosa over the apex of a tooth, buccal or lingual, signals the further spread of inflammation from the periodontal ligament to the periosteum overlying the bone. This examination is most effective when it can be made bilaterally at the same time (Figure 6-7). Besides the pain response to this test, information can also be obtained about asymmetry and fluctuation in the areas examined. Sometimes because of excessive swelling and associated severe pain, it is difficult to diagnose fluctuation (subperiosteal abscess).

**Electric Pulp Test.** Although any stimulus can initiate a neural response, be it thermal change or physical contact with the dentin and pulp, the most frequent
testing device has been some form of electric pulp tester. Presently, there are a number of very efficient, battery-powered, and easily controlled devices on the market. All have sophisticated circuitry and digital display. Price is the major difference between the various brands, foreign or domestic. Examples are the Digitest and Gentle Pulse (Parkell Products; Farmingdale, N.Y.) Vitality Scanner and Endoanalyzer (Sybron Analytic Technology; Orange, Calif.), Trilite (Evident/Pulpdent, UK and USA), Pulppen (Hygenic Corp., USA), Sirotest (Siemens AG, Germany), Digipex II (Mada Equip. Co., Japan and USA), Neotest (Amadent; Cherry Hill, N.J.), and the Dentometer (Dahlin, Denmark, UK, and USA).

In contrast to the older types of electric pulp testers, these devices produce little discomfort, even when operated by inexperienced examiners (Figure 6-8). It is important to follow the manufacturer's instructions to establish positive contact.

The testing procedure must be explained to the patient. An apprehensive or confused patient or a malingering patient may give erratic responses and invalidate the testing. It may be necessary to practice testing on teeth other than the ones being examined to help the patient get used to the procedure. As with most tests, electric pulp testing (EPT) should not be used as the only method for diagnosis.

Electric Pulp Testing Procedures. To achieve consistent results with an electric pulp tester, one must follow a standard procedure. Dry the teeth to be tested and isolate them with cotton rolls. Cover the tip of the electrode with toothpaste or a similar electrical conductor. To stimulate the pulp nerve fibers, the electric current must complete a circuit from the electrode through the tooth, through the patient, and back to the electrode. When gloves were not routinely used by dentists, the ungloved fingers of the dentists completed the current by contacting both the electrode and some part of the patient's face, usually the cheek. With gloved hands, that connection is interrupted.

To establish a complete circuit using rubber gloves, one of two methods must now be followed. A ground attachment may be clipped on the patient's lip (see Figure 6-8, D), or the patient may complete the circuit by placing a finger on the metal electrode handle. The latter method has the advantage of giving the patient more control: simply lifting the finger off the electrode handle when a sensation is felt will immediately interrupt the current and terminate the stimulation (Figure 6-8, C).

A record must be made of the results of each tooth tested. If repeat tests are indicated, it is probably better
to use the same pulp tester each time for more accurate comparison. Being able to quantify results numerically is a decided advantage of EPT over thermal testing.

Multirooted teeth may need to be tested by placing the electrode on more than one crown location. It may happen that two areas on a molar will give a negative response, but a positive test within the normal range may be gained in another area. This may indicate that the pulp in two canals is necrotic, whereas the pulp in the third canal is still vital.

If CO₂ dry ice testing is not possible and if it is imperative that a tooth fully covered by gold or porcelain be electrically pulp tested, a cavity is prepared without anesthesia, through the restorative material, until the dentin is reached. During preparation, penetration to the dentin may be sufficient enough to elicit a response. If not, the probe is placed directly on dentin and the response noted. To avoid contacting the metal of the crown, a tiny piece of “spaghetti” tubing can be used to insulate the tester probe. Analytic Technology also makes a Mini-Tip for this purpose, or a small instrument such as an endodontic file may be used as a “bridging” device.48

Precautions in Use of an Electric Pulp Tester. It has been suggested that using an electric pulp tester on patients who have an indwelling cardiac pacemaker is

Figure 6-8 Use of an electric pulp tester. A, Posterior teeth should be isolated and dried. Mylar strips can be used to separate connecting metallic fillings. Using toothpaste as a conductor, contact should be made on the occlusal third. B, Isolated and dried anterior teeth are contacted on the incisal third to avoid false stimulation of gingival tissue. C, Vitality Scanner pulp tester. To complete the circuit, the patient may touch the metal handle. D, Digitest pulp tester with lip contact to complete circuit. Both pulp testers have a digital readout. The difference lies in size and price. A and B reproduced with permission from Marshall FJ. Dent Clin North Am 1979;23:495. C courtesy of Analytic Technology. D courtesy of Parkell Products.
contraindicated. After testing the effect of electric pulp testers on dogs with artificial pacemakers, Woolley and associates concluded that currents of the magnitude of 5 to 20 milliamps are sufficient to modify normal pacemaker function.49 After testing one battery-powered device and three using line current, they found that only one caused interference with pacemaker action. They also warned against devices such as desensitizers and electrosurgical units that could produce unknown current leaks, as one of the pulp testers did.

**Liquid Crystal Testing.** Cholesteric liquid crystals have been used by investigators50 to show the difference in tooth temperature between teeth with vital (hotter) pulps and necrotic (cooler) pulps. The laser Doppler flowmeter has also been shown to measure pulpal blood flow and thus the degree of vitality.51–53 Already used in medicine (retina, renal cortex), this experimental device might well spell the difference between reversible and irreversible pulpitis—the stressed pulp, if you will.

The Hughes Probeye camera, which is capable of detecting temperature changes as small as 0.1°C, has also been used to measure pulp vitality experimentally.54 All three of these methods measure blood flow in the pulp, the true measurement of pulpal status. One may emerge as the pulp tester of the future.

**Occlusal Pressure Test.** A frequent patient complaint is pain on biting or chewing. The causes for such symptoms include apical periodontitis, apical abscess, and incomplete tooth fractures (infractions). A clinical test that simulates the chief complaint is the occlusal pressure test (or biting test). Several methods exist, such as biting on an orangewood stick, a Burlew rubber disk, or a wet cotton roll. All have the ability to simulate a bolus of food and allow pressure on the occlusal surfaces.

The orangewood stick, the Tooth Slooth, and Burlew disks allow pinpoint testing of individual cusp areas, whereas the wet cotton roll has the advantage of adapting to the occlusal surface, allowing for pressure over the entire occlusal table. This test is useful in identifying teeth with symptoms of apical periodontitis, abscess, or cracks. An interesting clinical observation in patients with tooth infractions (cracked tooth syndrome) is pain often experienced when biting force is released rather than during the downward chewing motion.

**Anesthetic Test.** Pain in the oral cavity is frequently referred from one tooth to an adjacent one or even from one quadrant to the opposing one. The anesthetic test can help identify the quadrant from whence the focus of pain originates. The suspected tooth should be anesthetized, and, if the diagnosis is correct, the referred pain should disappear, even when it is referred to the opposite arch.

**Test Cavity.** This test is often a last resort in testing for pulp vitality. It is important to explain the procedure to the patient because it must be done without anesthesia. Make a preparation through the enamel or the existing restoration until the dentin is reached. If the pulp is vital, the heat from the bur will probably generate a response from the patient; however, it may not necessarily be an accurate indication of the degree of pulpal inflammation. As with other tests, the cavity test must be used in conjunction with the history and other testing procedures and not used as the sole determinant.

**The Stressed Pulp**

Abou-Rass has directed the attention of the profession to what he calls “the stressed pulp.”5 This is the pulp that over the years has been stressed by both disease and treatment (caries and periodontis; trauma—impact, occlusal, and iatral; chemicals—cements, resins, and amalgams). This is the tooth that has decayed and been restored then re-restored, cut down, heated up—all of the insults a pulp is subjected to over a long span of time.

In addition, when the tooth is now ready to be used as an abutment for an important partial denture, fixed or removable, still more iatral insult follows. Careful as one might be, the tooth must still be reduced some more, heated up, cooled off, and injured by impressions, try-ins, and temporaries. The final insult is permanent cementation followed by microleakage.

Is it any wonder that a number of these stressed pulps finally give up by either aching and dying or just quietly dying? But the tragedy is that the tooth is now covered by a beautiful new restoration that will have to be weakened or destroyed to reach the ailing pulp. Would it not have been better, asked Abou-Rass, to have determined the quality of life of the pulp before treatment and have taken action before, not after, the final commitment has been made?5

How does one determine which pulps are stressed? By taking a careful history and examination, of course. The dentist must consider the patient’s lengthy report on this particular tooth, the radiographic outline of the pulp cavity, and the examination findings. The examination includes transilluminating; probing; percussing; examining for cracks, crazing, and abrasion; and the response to pulp testing, thermal and electrical.

Any negative results should be viewed with suspicion, including past trauma, orthodontic movement, multiple or deep restorations, poor systemic health, irradiation in the area, tooth coloration, structural cracks, defective
Periodontal Evaluation

No dental examination is complete without careful evaluation of the teeth’s periodontal support. Periodontal probing and recording pocket depths provide information with respect to possible etiology and prognosis (see following sections).

There is little question that pulpal necrosis can lead to loss of periodontal support. Whether periodontal disease can cause pulpal degeneration is a question not clearly answered. There is agreement, however, that a potential interaction exists between the pulp and periodontium. For the purposes of endodontic treatment of a single tooth, probing may be limited to the tooth involved and at least the adjacent teeth. As part of a total oral examination, all teeth should be included in the probing evaluation. The number of probing locations may vary depending on the tooth’s location. Four to six areas surrounding the tooth should provide a good picture of periodontal support. Gingival and sulcular bleeding and drainage, along with the presence of plaque and calculus, should also be noted.

FACTORS INFLUENCING PROGNOSIS

Endodontic diagnosis should not be the sole determinant of treatment planning. Other factors contribute to determine whether a suspicious tooth should be restored or a pulpally involved tooth should be treated. Periodontal health, restorative considerations, and radiographic evidence of anatomic complexities associated with the tooth will have a major impact on any treatment decision.

Periodontal Disease

Periodontal stability is a basic requirement for any tooth being considered for endodontic therapy. This stability is determined by the amount of bony support, the health of that support, and the health of the overlying soft tissue. Examination alone cannot guarantee the future health of these tissues, but usually it can determine existing disease. Isolated bone loss or tooth mobility may or may not signify periodontal disease. It may be owing to periradicular disease of pulpal origin, or it may be combined periodontal-endodontal disease.

Generalized bone loss of periodontal disease will definitely affect prognosis and therefore the treatment plan. As part of the examination, probe the sulcus of the tooth or teeth in question and record the pocket measurements. Also test for mobility and record the data using a system of 0 through 3. Grade 0 means normal mobility, grade 1 slight mobility, grade 2 marked mobility, and grade 3 mobility and depressable. Also record if bleeding occurs on probing. Particular note should be made of palatal grooves in single rooted teeth (Figure 6-9), furcations in multirooted teeth, and other anomalies (enamel projections, etc), as these may aggravate gingival conditions and make for unstable future periodontal health. These examinations will establish approximate bone levels and the crown-root ratio. The presence of 3 to 5 mm pockets of a first-degree mobility indicates “moderate periodontitis” (Figure 6-10). When this is found, the entire mouth should be screened for periodontal disease and treated accordingly.

Pockets deeper than 5 mm, or mobility graded 2 or 3, indicate “severe periodontitis,” and periodontal treatment is imperative. Referral to a periodontist should be considered. Regardless of the extent of the periodontal disease or who renders the treatment, the patient must be advised of the effect that periodontal disease can have on the prognosis for endodontic therapy. Hiatt reported 20-year follow-up on two cases involving a number of teeth treated with combined periodontal/endodontal therapy. Only one tooth was lost, because of root resorption.

Restorability

The restorability of a tooth requiring endodontic treatment depends on the amount of sound tooth structure remaining and the effect that the restoration will have on the periodontal tissues—not invading the “biologic width” between restoration and the periodontal ligament (PDL), for example. Prior to any endodontic treatment, and after all present coronal restorations and caries are removed, the remaining tooth structure should be re-examined with a fiberoptic light for fractures and perforations. At this time, teeth with vertical fractures or severe perforations are generally untreatable.
It should also be noted that pulpless teeth are not strengthened by the use of posts. Posts are for the retention of crown build-up. Retention of the crown and strength of the restoration depend on the design of the restoration, placing margins well onto solid tooth structure.

RADIOGRAPHIC EXAMINATION

In the sequence of examination, radiographic evaluations should come last. In practical terms, one usually takes a look at the radiographs first and then proceeds with the other evaluation. Following the examination, in
hindsight, radiographs can be better interpreted when the results of the previous examination are available.

First, a few words about endodontic radiographs. The radiographic image is a shadow and has the elusive qualities of all shadows. First and foremost, it is a two-dimensional representation of a three-dimensional object (Figure 6-11). Also, like any shadow, it may be too light or too dark, too short or too long. The central beam must be carefully oriented to give detail where detail is required (Figure 6-12). This usually requires the central beam to be aimed directly through the periapex rather than a compromise position at the crest of the alveolar process.

In addition to central beam positioning, two or more exposures are frequently necessary to check out detail from more than one horizontal angle (Figure 6-13). This is especially true in the case of the normal bony foramens. The mental foramen may be directly superimposed over the apex of the mandibular premolars, for example (Figure 6-14). The nasopalatine foramen also may be superimposed on the apex of the maxillary central incisors. Because these foramina are actually some distance from the apices of these teeth, their shadows may be shifted far to the mesial or the distal merely by shifting the horizontal angle of the cone of the x-ray machine to the mesial or distal during separate exposures (Figure 6-15). On the other hand, if the radiolucent area in the radiograph is actually a lesion truly associated with the periapex of the involved tooth, its shadow will remain “attached” to the root end and will remain so in spite of a mesial or distal shift in separate films. For details regarding the “horizontal shift,” the reader is referred to chapter 9.

**Interpretation**

The finest radiologist will be severely handicapped in securing valuable information from a film that has not been properly placed, exposed, and processed. Conversely, the finest film is of limited value if the interpreter is inadequately trained.

Neaverth and Goerig have emphasized the necessity of knowing the normal structures before interpreting the abnormal (personal communication, 1995). Using radiographs of unusual clarity, they have delineated the anatomic structures of the posterior mandible and
Figure 6-12 The importance of an adequate radiograph. A number of important details may be learned from this film: (1) size and character of periradicular lesion, (2) curvature of root end, (3) relationship of root to adjacent roots, (4) mesial or distal inclination of root, (5) approximate length of tooth, (6) relationship of exploring instrument to root curve, (7) size of canal, and (8) divergence of coronal cavity (arrow). Periodontal lesions and root fractures could also be apparent. A central beam, directed through the periradicular region, gives clarity to this important area.

Figure 6-13 Variations in horizontal angle improve radiographic interpretation. A, In this straight-on, labial-lingual projection, an internal resorption defect is seen. B, In a mesially directed projection, the extension of the resorptive defect to the mesial-lingual is apparent.
maxilla (Figure 6-16). Many times, these structures can imitate or hide lesions of endodontic or nonendodontic origin. It is also important to identify structures such as the mandibular canal and maxillary sinus and approach them with caution during endodontic treatment and surgery. Encroachment into these areas has led to numerous lawsuits.\textsuperscript{59}

An organized method of evaluating and interpreting radiographs, from a single film to a full-mouth set or a panographic plate, has been suggested by Wuehrmann.\textsuperscript{60} This technique recommends \textbf{reviewing one structure at a time}, such as the lamina dura. Follow this structure all the way around the first tooth on the left and then around the next tooth and the next until the full-film or full-mouth survey is scanned. The findings are recorded as normal or changed.

Brynolf has paid special attention to the continuum of the lamina dura and the periodontal ligament space.\textsuperscript{61} She has pointed out the normal appearance of the lamina dura at the apex, which, under magnification, can be seen dipping down into the apical orifice. If there is slight inflammation at the apex, the lamina dura is lost as the PDL space widens\textsuperscript{62} (Figure 6-17). Kaffe and Gratt at Tel Aviv University found much the same as Brynolf, that the best radiographic features for accuracy in diagnosis were lamina dura continuity and PDL width and shape.\textsuperscript{63}

Following Wuehrmann’s suggestion, one proceeds to the next structure, for instance, the crowns of the teeth.\textsuperscript{60} Each crown is evaluated independently. The

\begin{figure}[h]
\begin{center}
\includegraphics[width=\textwidth]{image1}
\end{center}
\caption{Mental foramen is superimposed exactly at the apex of a vital mandibular premolar and may easily be mistaken for a periradicular lesion.}
\end{figure}

\begin{figure}[h]
\begin{center}
\includegraphics[width=\textwidth]{image2}
\end{center}
\caption{Example of a method used to determine the relationship of radiolucency to the periapex of a tooth. A, The nasopalatine foramen is superimposed over the periapex of a right central incisor. The right lateral incisor is missing. B, By changing the horizontal projection, the shadow of the nasopalatine foramen may also be superimposed over the periapex of the left central incisor, proving that the radiolucent area is some distance lingual to the apex of both teeth.}
\end{figure}
The crest of the alveolar process should then be followed from left to right, upper to lower, and all of the structures outside the alveolar process should be evaluated as well—the sinuses, floor of the nose, foramina, and so on. In short, radiographic interpretation should be done in an organized habitual way so that nothing is overlooked.

Tracing the dark periodontal membrane space will reveal the number, size, and shape of the roots and their juxtaposition. While observing the roots, one must look for periradicular lesions and root defects such as anomalies, fractures, and external resorption. The number, curvature, size, and shape of all of the canals and chambers should be noted along with internal resorption, pulp stones, linear calcification, and open apices.

For example, if a large pulp chamber is seen in a single adult tooth while other chambers are narrowing, one should suspect a necrotic pulp, even though a periradicular lesion might not be apparent. In marked contrast, Swedish dentists have reported dramatic narrowing of pulp chambers in patients with serious renal disease, particularly those with transplanted kidneys who are on high doses of corticosteroids.64

Radiographic coronal evaluation includes depth of caries and restorations with respect to the pulp, as well as evidence of pulp cappings or pulpotomy, dens invaginatus or dens evaginatus, and the size of the preparations under porcelain or resin jacket crowns.

Evaluation, however, comes down to a matter of personal interpretation, as demonstrated by Goldman and
his colleagues. The radiographs of 253 cases, originally examined by three faculty members at Tufts University, were re-examined by them 6 to 8 months later. These endodontists agreed with themselves from 72 to 88% of the time. Ten years later, however, the same group repeated essentially the same experiment with 79 other dentists and found that they not only disagreed with each other over half the time but, worse yet, disagreed with themselves 22% of the time. Much the same was found by researchers in Israel and Greece.

Antrim found that holding the radiograph up to a view box produced more consistent agreement among examiners than either projecting the radiograph or using a magnifying glass. However, Weine has claimed that projecting the image produces the best interpretative result. One of the reasons for these discrepancies, of course, deals with how one interprets bony lesions. Shoha et al. were able to demonstrate the variables in this interpretation. They found that lesions were always larger than their radiographic image, especially in the mandibular molar region. Lesions in the premolar area were only slightly larger than their radiographic image. Lesions found by hindsight were often difficult to detect initially because of their vague outline. In Holland, it was found that cortical bone had to be damaged by an osseous lesion before radiolucency could be detected and that loss of cancellous bone alone was not enough to be visible radiographically.

Bender has illustrated this dramatically with a radiograph of a molar tooth showing increased density of the bone at the periapex (Figure 6-18, A). Yet when the tooth was extracted, a huge granuloma was attached, which was not at all apparent in the film (Figure 6-18, B).

Root Anatomy

The radiographic examination provides essential information relative to normal and abnormal root formation. Since mandibular incisors frequently have two canals and, at times, two roots, adding an additional radiographic view from the mesial or distal can aid in detecting such anatomic variances.

One can expect anatomic variations in all tooth locations. Mandibular premolars and molars are no exception (Figure 6-19). By both radiographic and mechanical means (Figure 6-20), the number of canals and foramina should be determined before canal enlargement is completed. Because of frequent variations, it is a good habit to examine radiographs with a magnifying glass so as not to miss an extra canal or other variations.

Maxillary first premolars with three roots or canals are seen more clearly if the projected horizontal direction of the central beam is slightly from the mesial
(Figure 6-21). The normal two roots or two canals of the maxillary first premolar also are easier to find if the beam is directed from the mesial. A recent in vivo study showed that two canals are present in maxillary second premolars 59% of the time, more than had been reported previously.74–77 The mesial angulation technique is therefore beneficial in detecting the second canal in maxillary second premolars. In this case, the lingual root always appears to the mesial on the film (the SLOB rule—Same Lingual-Opposite Buccal).78

Slowey has demonstrated how difficult it is to detect extra roots, let alone extra canals.79 One particularly baffling case involved a maxillary lateral incisor with an unusual second root. In the post-treatment radiograph, a bony lesion could be seen to the distal (Figure 6-22, A), but it was assumed that the lesion was related to invagination from the cingulum. Because the lesion did not heal, the tooth was extracted, and only then was the extra root revealed (Figure 6-22, B and C). A radiograph of the contralateral incisor revealed what appeared to be a bilateral anomaly (Figure 6-22, D). As Slowey pointed out, “whenever the outline of the root is unclear, has an unusual contour, or strays in any way from the expected radiographic appearance, one

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**Figure 6-18** Radiographic deception owing to the thickness of the cortical bony plates. A, Osteosclerosis distal to the second molar completely masks a huge bony lesion within spongy bone. B, Same tooth extracted with an enormous space-occupying granuloma (arrows), not in the least suspected radiographically. Reproduced with permission from Bender IB.73

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**Figure 6-19** A, Mesial root of first molar has not only two separate canals but an additional root as well (arrow). B, Two premolars with an unusual root and canal formation. “Fast break” in canal radiodensity (arrows) indicates canal bifurcation. Both teeth have three and possibly four canals, but the number of apical foramen can be determined only by instrument placement (see Figure 6-21). Reproduced with permission from Slowey RR.79
should suspect an additional root canal…” He quoted Worth, who said, “Look at the corners of the radiograph and the center will take care of itself.”

The mystery of extra canals within the normal number of roots is more perplexing than the extra root problem itself. Slowey has also given us some tips on how to detect the undetected. One method is to follow the image of the test file in the length-of-tooth film, particularly in the coronal part of the root. If an extra dark line is apparent in the coronal third of the root, running parallel to the instrument (Figure 6-23), one should suspect a second canal. This is especially true in the mesiobuccal root of maxillary first molars, where a fourth canal is found 51.5 to 69% of the time in vitro but only 18.6 to 33.3% in vivo. Fourth canals frequently occur in the distal roots of mandibular first molars as well (Figure 6-24).

Another diagnostic clue was pointed out by Slowey. It could be called “the fast break.” When viewing a radiograph, if there is a sudden change in the radiolucency within a canal, this change in density probably signals the beginning of an additional canal (Figure 6-25), a frequent occurrence in maxillary first premolars. In mandibular canines (Figure 6-26, A), such observations should be followed up by taking additional radiographs from a different horizontal angle (Figure 6-26, B) and possibly searching out the extra canals with the length-of-tooth instrument films (Figure 6-26, C).

Frequently, root formation results in severe curvature. When the curvature is to the mesial or distal, so frequently seen in the maxillary lateral incisors or occasionally in premolars (Figure 6-27), there is little problem...
Figure 6-22  A. Continuing lateral lesion (mesial) and acute abscess (arrow). The tooth is finally extracted. B, Benchtop radiographic view reveals a second root and an unfilled canal (arrow), not seen in the original films. C, Lingual view of second root and invagination from the cingulum. D, On the contralateral side, a similar anomaly exists. Reproduced with permission from Slowey RR.79
Figure 6-23  A, From viewing the initial film, one would not suspect that there are two canals in the mesiobuccal root of the first molar. B, An extra dark line alongside the exploring instrument (arrow) signals the possibility of a second canal. C, Final film showing two separate mesiobuccal canals (arrow) apparently arising from a common orifice. Reproduced with permission from Slowey RR.79

Figure 6-24  A, Two instruments in a single canal, but a wide, extra dark line (arrow) indicates an additional canal. B, Final filling proves four canals. Reproduced with permission from Slowey RR.79
Figure 6-25  A, Sudden change in radiographic density (arrow) signals probable canal bifurcation at that point. B, Change from right-angle horizontal projection (A) to 20-degree projection from the distal clearly reveals two canals but a single foramen. Reproduced with permission from Slowey RR.79

Figure 6-26  A, "Fast break" in radiograph of a mandibular canine (arrow) indicates that a search should be made for a second canal. B, Varying horizontal projection reveals two canals in hourglass-shaped root. C, "Length-of-tooth" instruments in place reveal a single foramen. Reproduced with permission from Slowey RR.79
in detecting the curvature. However, when the curvature is to the buccal or lingual—in the same plane as the central x-ray beam—the curvature is more difficult to detect (Figure 6-28). Careful examination may reveal increased radiopacity at the root end as the root doubles back on itself and is literally “x-rayed” twice. In its extreme, a peculiar “target” or “bull’s-eye” appearance will show in the film (Figure 6-29).

In addition to “normal” variances in tooth form, such as curvatures and extra roots, anomalies that may
affect pulp vitality may also be detected in the radiographs. **Invagination** and palatal radicular groove (see Figure 6-9) are conditions that frequently have anomalous tracts leading from the enamel surface directly to the pulp (Figure 6-30). Such defects may involve the root, either partially or all the way to the apex. These grooves permit bacterial invasion of the pulp, which leads to periradicular lesions and pulp necrosis. Other anomalies such as odontome and microdont may also lead to pulp necrosis (Figure 6-31).

**Conditions Inside the Tooth**

Pulpal changes such as inflammation and necrosis cannot be detected radiographically within the canal. Only changes in calcific structures can be demonstrated. However, the results of pulp tissue changes are observable, that is, internal resorption as a result of irreversible pulpitis, periradicular bony changes resulting from pulp necrosis, and lack of continued root formation in immature teeth subjected to pulp destructive traumatic injuries.

**Pulp Stones.** Chronic pulpal disease may facilitate the formation of pulp calcifications such as pulp stones (Figure 6-32). However, the mechanism of pulp stone formation and the various factors necessary in the calcific process are not well known at this time, a fact illustrated by the observations that pulp stones are

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**Figure 6-29** “Target” or “bull’s-eye” phenomena seen in roots that severely curve to the buccal or lingual, that is, in the direction of the central beam. A, Central incisor with a dilacerated root under orthodontic realignment. B, Lateral head film in which the labially dilacerated root (in A) is apparent (arrow). C, Resection and retrofilling of the dilacerated root seen in A and B. (A and B courtesy of Dr. Alfred T. Baum; C courtesy of Dr. Dudley H. Glick.)

**Figure 6-30** Dens invaginatus in the cingulum area of a maxillary lateral incisor. Anomalous tract seen in this radiograph has led to pulp infection and periradicular pathosis.
found in apparently normal teeth with healthy pulps (Figure 6-33). Careful examination of radiographs may reveal other problems beside pulp stones—root fractures, calcification, early pulp death (Figure 6-34), and internal and external resorption.

**Internal Resorption.** Following traumatic injuries and/or caries, internal resorption may be detected on radiographs (Figure 6-35). Differentiation between internal and external resorption may be made radiographically. First, the lesion of internal resorption usually has sharp smooth margins that can be clearly defined (see Figure 6-35, A). However, it need not be symmetric. Another diagnostic sign is the manner in which the pulp "disappears" into the lesion, not extending through the lesion in its regular shape (Figure 6-35, B).

At times, an area of resorption may be confused with dental caries radiographically. However, dental caries is less sharply defined than is internal resorption. Neither caries nor internal resorption should be ignored; internal resorption can progress to the point of extensive tooth destruction and perforation.

Wedenberg and Lindskog, after experimentally producing internal resorption in monkey incisors, concluded that there are two types of internal resorption: transient, which may repair itself, and progressive, "the latter requiring continuous stimulation by infection."
From London, Lynch and Ahlberg reported bilateral idiopathic internal resorption. The radiolucent areas were cleanly defined, punched-out lesions. The pulp was seen to disappear into the lesion.88

Herpes zoster was linked to resorption in other cases. The varicella-zoster virus lies dormant for years in a nerve ganglion, from an earlier “chickenpox” attack, and can suddenly reactivate to infect the pulp.89

**Conditions Outside the Tooth**

One of the most common occurrences seen radiographically on the outside of the root of the tooth is external resorption.

**External Resorption.** Andreasen has stated that following traumatic injuries there are three main types of external root resorption: **surface, inflammatory, and replacement resorption.** Surface resorption is caused by acute injury to the periodontal ligament and root surface. Cell proliferation mediation removes the traumatized structures. If injury is not repeated, healing takes place with new cementum and PDL. **Inflammatory resorption** may occur from combined injury to the PDL and cementum complicated by bacteria from the infected root canal, which, in turn, stimulate the osteoclasts. Resorption usually ceases if the root canal is thoroughly debrided and obturated unless stimulation has provoked the third type of resorption, replacement resorption. In this type, ankylosis between bone and tooth occurs without the intervening PDL, and the constantly remodeling bone slowly removes the tooth and replaces it with bone. This is often seen in unsuccessful replant cases.90

Frank has delineated another type of external root resorption that he terms **extra-canal invasive resorption,** totally different from regular external or internal resorption.91 This phenomenon has interested clinicians and researchers over the last century and has been variously called **odontoclastoma,**92 **idiopathic external resorption,**93 **peripheral cervical resorption,**94 **cervical external resorption,**95 **peripheral inflammatory root resorption,**96,97 **cervical resorption,**98 and, more recently, **invasive cervical resorption.**99

Frank et al. made the point that extra-canal invasive is the more descriptive term100 (rather than “external-internal,” which Frank originally used) because of the external origin of this resorptive defect, before it invades the dentin (Figure 6-36), but, more
Figure 6-35  A, Radiograph of lesion of internal resorption (arrow). Note sharp smooth margins. (Courtesy of Drs. A. H. Gartner, T. Mack, R. Somerlott, and L. Walsh.) B, Drawing of internal resorption shows how the shadow of the pulp “disappears” into the huge lesion. Reproduced with permission from a drawing modified from Lepp FH. Oral Surg 1969;27:185.

Figure 6-36  A, Radiograph of lesion of extra-canal invasive resorption (arrow). Note the ragged margins of the lesion. (Courtesy of Drs. A. H. Gartner, T. Mack, R. Somerlott, and L. Walsh.) B, Drawing of resorption shows how the shadow of pulp “passes through” the lesion unaltered. Inset depicts external lesion perforating into and resorbing dentin. Reproduced with permission from a drawing modified from Lepp LH. Oral Surg 1969;27:185.
important, that the destruction surrounds the root canal without necessarily involving the pulp (Figure 6-37). This, of course, gives an entirely different radiographic appearance than internal resorption. In extra-canal invasive resorption, the pulp appears to pass through the lesion (Figure 6-38), whereas the pulp “disappears” in the internal resorptive lesion (see Figure 6-35).

The histopathologic characteristics of this insidious and often aggressive form of invasive tooth resorption are of interest and significance to clinicians. Although the invading tissue is derived from ectomesenchymal precursor cells within the periodontal ligament, it differs both in structure and behavior from the periodontal ligament. In early lesions, the invading tissue is fibrovascular (Figure 6-39), which accounts for the pinkish appearance that may be evident near the gingival margin of the affected teeth.99 Later, as resorption extends more deeply into radicular tooth structure, the histopathologic appearance may be described as fibroosseous—bone-like depositions being evident—both within the fibrovascular tissue and laid directly onto resorbed dentin surfaces (Figure 6-40). Of clinical significance is the deeply infiltrating channels that often interconnect with the periodontal ligament. Effective treatment can be achieved only if all ramifications are inactivated or removed (see chapter 12).

Jacob examined 18 of these cases and determined that the pulp spaces were separated from the resorptive areas by a “resistant dentin shell.”101 Quite possibly, this phenomenon of not invading the pulp relates to the character of the dentin surrounding the pulp. Clastic cells generally attack well-calcified structures such as bone, dentin, and cementum. The pulp, however, is surrounded by uncalcified predentin—uncalcified material not readily amenable to cellular clastic action. In addition, there is evidence for an anti-invasive factor in tooth dentin.102

Figure 6-37  Extra-canal invasive resorption. The integrity of the root canal is evident in the extracted molar (larger arrow). Note the file (smaller arrow) extending into the canal. (Courtesy of Dr. Harold Gerstein.)

Figure 6-38  Frank’s classification of extra-canal invasive resorption. A, Supraosseous, the most frequent form. Inset depicts external invasion and dentin destruction, yet intact pulp. Note that the cross-section does not invade the pulp. B, Intraosseous: it is difficult to determine the point of origin radiographically. C, Crestal, which may be related to orthodontic movement. (Courtesy of Dr. Alfred L. Frank.)
Although most extra-canal invasive root resorption occurs at the immediate subgingival level — supraosseous, if you will (see Figure 6-38, A)—Frank et al. described an additional intraosseous variation that is difficult to locate radiographically since it is not accompanied by periodontal breakdown.\textsuperscript{100} There may, however, be an open lesion just at or beneath the gingival sulcus (Figure 6-41, A). In addition, the resorption may extend into the coronal tooth structure, and a “pink tooth” may result (Figure 6-42), much the same as with coronal internal resorption. This may be more apt to happen with what Frank described as a crestal variety of invasive resorption (see Figure 6-38, C).\textsuperscript{91} If the lesion is visible radiographically, but not apparent visually, it may be probed for with a curved explorer.

The intraosseous variety of extra-canal invasive resorption (see Figure 6-38, B) is characterized radiographically as having an irregular moth-eaten appearance within the tooth—the more advanced, the more radiolucent (see Figure 6-41, B). Again, close examination will show the outline and integrity of the canal that appears to “pass through” the lesion unaltered (Figure 6-43). The pulp usually tests vital and has been asymptomatic. The radiographic appearance of these lesions varies. In early lesions, a small radiolucency may

Figure 6-39  Histologic appearance of an incisor tooth with extensive invasive cervical resorption. An intact layer of dentin and predentin on the pulpal aspect (*) separates the pulp from the resorbing tissue. The resorption cavity is filled with a mass of fibrovascular tissue with active mononucleated and multinucleated clastic cells lining resorption lacunae (arrows). (Original magnification ×40.) (Courtesy of Dr. John McNamara; reproduced with permission from Heithersay GS.\textsuperscript{99})

Figure 6-40  Histologic appearance of an extensive invasive cervical resorption with radicular extensions. Masses of ectopic calcific tissue are evident both within the fibrovascular tissue occupying the resorption cavity and on resorbed dentin surfaces. In addition, communicating channels can be seen connecting with the periodontal ligament (large arrows). Other channels can be seen within the inferior aspect of the radicular dentin (small arrows). (Original magnification × 30.) Reproduced with permission from Heithersay GS.\textsuperscript{99}
emerge—somewhat irregular in appearance—that may, on occasion, resemble dental caries.

Extra-canal invasive resorption may also radiographically resemble internal resorption (see Figure 6-43, A). To differentiate, off-angle mesial and distal radiographs will “move” the extra-canal type of resorption, whereas the internal resorptive defect will not move on the film (see Figure 6-43, B).

Although the etiology of extra-canal invasive resorption is unknown, several potential causative factors have been identified and recently analyzed. Heithersay studied 222 patients, with a total of 257 teeth, exhibiting varying degrees of invasive cervical resorption103 (Figure 6-44). Orthodontics alone was the most significant causative factor104–106 (21.2% of patients, 24.1% of teeth), whereas trauma was the next most identifiable potential cause accounting for 14.0% of patients and 15.1% of teeth. Often this type of resorption was associated with a combination of factors, for example, trauma and bleaching. Bleaching as a sole factor was found in 4.5% of patients and 3.9% of teeth.

Other factors identified as potential predisposing factors, but at a low level, were surgery, periodontics,
Figure 6-43  Extra-canal invasive resorption, supraosseous. A. Lesion (arrow) superimposed over the canal. B. Same tooth, radiographed from the mesial; the lesion "shifts" (arrow) within the tooth. Pulp tests are vital. (Courtesy of Dr. Alfred L. Frank.)

Figure 6-44  Heithersay’s clinical classification of invasive cervical resorption: Class 1: A small invasive resorptive lesion near the cervical area with shallow penetration into the dentin. Class 2: A well-defined invasive resorptive lesion that has penetrated close to the coronal pulp chamber but shows little or no extension into the radicular dentin. Class 3: A deeper invasion of dentin by resorbing tissue, not only involving the coronal dentin but also extending at least to the coronal third of the root. Class 4: A large invasive resorptive process that has extended beyond the coronal third of the root canal. Reproduced with permission from Heithersay GS.99
bruxism, delayed eruption, developmental defects, and interproximal stripping. The potential for invasion via a crack in extensively restored teeth was identified. The clinical classification in Figure 6-44 is also of importance when assessing teeth suitable for treatment, as discussed in chapter 12. Suffice it to say, Class 1 to 3 lesions must be completely débrided and inactivated and, if not pulp invasive, filled with a suitable restorative material such as dentin adhesive and composite resin (Figure 6-45), glass ionomer cement, or, in some situations, mineral trioxide aggregate. The extensive Class 4 lesions are not suitable for current therapy, and no treatment or extraction is recommended.

Radiographic Diagnosis: Periradicular Lesions
Pulpal inflammation and necrosis eventually produce periradicular changes. The earliest is a widening of the periodontal ligament space, usually at the apex.

Periradicular Lesions. Most often a widened PDL space and inflammatory apical root resorption are associated with pulp necrosis and infection. Occasionally, however, these signs may be associated with occlusal traumatism (Figure 6-46). This emphasizes the need for additional tests beyond radiographs. A widened PDL space may also be expected with other conditions: acute apical periodontitis, a beginning acute apical abscess, or, occasionally, acute pulpitis.

Apical External Resorption. With this condition, the apex may range in appearance from slightly blunted (Figure 6-47, A) to grossly resorbed (Figure 6-47, B), caused by the pressure from orthodontic movement.\(^1\)\(^2\)\(^3\)\(^4\)\(^5\) It also may be obliquely resorbed (Figure 6-48, A) or have a cupped-out appearance (Figure 6-48, B), or it may resemble the chewed appearance of a tree felled by a beaver (Figure 6-48, C). In any event, if apical resorption has taken place, the apical foramen will be in the center of the root. If the root resorption has a “moth-eaten” appearance, it is possible that the tooth, by accident, was ripped loose from its ligaments and/or was replanted. Sometimes an unexplained lesion in the region strongly suggests a malignancy (see Figure 5-32).

Condensing Osteitis. The exact opposite of root resorption is condensing osteitis. Teeth with chronic pulpal inflammation sometimes exhibit increased apical bone calcifications, which have a radiopaque appearance on x-ray films (Figure 6-49). Initially, the root may have been blunted by inflammatory resorption, and then this space is filled by osteosclerotic bone. Following successful root canal therapy, the regional radiopacity slowly changes back to a normal appearance\(^1\)\(^2\) (see Figure 5-9). Both idiopathic and sclerosing osteomyelitis result in bone hypercalciification as well.\(^1\)\(^0\)\(^9\)\(^1\)\(^1\)\(^0\)

Radiographic Changes as Sequelae to Pulp Necrosis. The severe periradicular osseous lesions that develop as sequelae of pulp necrosis are by far the most frequently observed changes. Associated with asymptomatic apical periodontitis (AAP) is a well-circumscribed osseous lesion. Radiographically, it appears as a radiolucent area, varying in size from a few millimeters to a centimeter or larger in size. The bony perimeter of the lesion may appear radiopaque (Figure 6-50). These lesions do not always appear at the periapex. Occasionally, they are seen on the lateral surface of the root associated with an accessory canal (Figure 6-51).
Figure 6-47  A, Blunted apices of teeth moved orthodontically more than 60 years ago. B, Massive root resorption associated with orthodontic tooth movement. Note the development of periodontitis as well. (B courtesy of Dr. Bradley H. Gettleman.)

Figure 6-48  A, Total pulp calcification and external root end resorption following injury of a mandibular second premolar. B and C, Two forms of apical external resorption. B, A resorptive defect leaves a flaring apical foramen that could not be adequately obturated by conventional methods. C, Advanced external resorption of the apex makes conventional instrumentation hazardous. B and C reproduced with permission from Luebke RG, Glick DH, Ingle JI. Oral Surg 1964;18:97.
The radiographic appearance of an **asymptomatic apical abscess** (AAA) is generally that of a larger, more diffuse, and irregular radiolucent lesion (Figure 6-52). This lesion may also drain into the mouth through a sinus tract or extraorally onto the neck or chin (Figure 6-53). An **apical cyst** may also develop out of a chronic abscess. In this case, the lesion appears more circumscribed, more like a “granuloma” in appearance (Figure 6-54, A). It is also pathognomonic of cysts to move the roots of teeth laterally (Figure 6-54, B). Natkin et al.
Figure 6-52  A, Diffuse radiolucent appearance (arrow) of an asymptomatic apical abscess (AAA) (with stoma) is here contrasted with an asymptomatic apical periodontitis (AAP) associated with a lateral incisor (no stoma). B, Asymptomatic apical abscess with drainage through buccal stoma following chronic infection of an apical cyst. Huge diffuse radiolucency is typical of AAA. The root of the tooth is displaced laterally by pressure from the cyst.

Figure 6-53  A, Diffuse radiographic appearance (right arrow) of an asymptomatic apical abscess may be overlooked owing to radiopacity of the heavy cortical bone. Also noted are condensing osteitis and external root resorption from chronic pulpitis (left arrow), as well as an anomalous third root of the third molar. B, Extraoral stoma (neck) of 8 years duration, draining from the chronic apical abscess seen in A. Immediately following root canal therapy, the discharge ceased, and the stoma healed to a “navel” of scar tissue.
Figure 6-54 Movement of teeth is pathognomonic of a cyst. A, Root separation beginning from modest cyst development. Typical circumscribed radiopaque perimeter may be confused with asymptomatic apical periodontitis. B, Pulpless lateral incisor with infected apical cyst. The canine has been particularly displaced. C, Lateral cyst (arrow) not involved with a pulpless tooth. D, Same case, 14 months later. Teeth remain vital. Biopsy, lateral periodontal cysts. C and D reproduced with permission from Degering CI. Oral Surg 1971;32:498.
postulated that the larger the lesion, the more apt it is to be a cyst.\textsuperscript{111}

In the event that one of these inflammatory lesions is in contact with the floor of the maxillary sinus, chronic sinusitis may result (Figure 6-55).

Lesions of Nonendodontic Origin. A number of pathologic changes in and near the alveolar process may be mistaken for periradicular lesions of pulpal origin. First to consider would be the nonodontogenic cysts: the so-called "globulomaxillary" cyst, the midline palatal cyst, and the cyst of the nasopalatine canal or foramen. Because these cysts are not associated with the exact root end, they may be "moved" radiographically around and away from the root ends if the horizontal direction of the central x-ray beam is varied from side to side (Figure 6-56). Residual cysts, as well as globulomaxillary cysts, may be found along the lateral surface of the root (see Figure 5-29).

To be further considered in the differential diagnosis of cysts is the vitality of the pulps of associated teeth. The pulp of a tooth with an apical cyst should test nonvital. This may not be true of the teeth near nonodontogenic cysts, unless traumatic injuries caused pulp death and also triggered sutural cyst formation. Weine and Silverlade pointed out that residual cysts may masquerade as periradicular lesions as well.\textsuperscript{112} It should be noted that there is controversy as to whether globulomaxillary cysts exist as a clear entity.

Periodontal lesions may be mistaken for periradicular lesions of endodontic origin (Figure 6-57). The periodontal probe and pulp tester are invaluable in determining the origin of the lesion. An additional method is to place a silver or gutta-percha point in the periodontal pocket and take a radiograph. If the lesion is traceable to the apex of a tooth but the pulp responds to pulp testing, the evidence for primary periodontal involvement is strong.

Common errors in diagnosis center around the lesions of periradicular osteofibrosis or cementoblastoma, particularly during stage 1, when radiolucency is so apparent (Figure 6-58, A and B). By the time the lesion begins to calcify into a sclerotic lesion (Figure 6-58, C to E), little doubt should exist about the nature of the lesion. Errors will still be made, however, in spite of all evidence to the contrary. The pulp tester will invariably help determine the diagnosis. A group in Great Britain has noted that osteofibrosis can be associated with hyperparathyroidism, which, in turn, may be familial.\textsuperscript{113}

In marked contrast, Marks and Dunkelberger have pointed out that Paget’s disease of bone (osteitis deform-
mans) often presents oral findings—atypical facial neuralgia and/or paralysis, hypercementosis, generalized pulp calcification, loss of lamina dura, root blunting by resorption, and loss of normal bony trabeculation\(^{114}\) (Figure 6-59, A and B). Any one sign or symptom can easily be confused with a host of localized diseases.

**Importance of Endodontic Radiography**

Radiography is of paramount importance to the practice of endodontics. It would be virtually impossible to obtain good results from treatment without the use of radiographs. One needs excellent diagnostic films before treatment begins, during treatment (in spite of the availability of electronic apex locators), and to evaluate treatment results after completion of endodontic therapy. On the other hand, one must not become totally dependent on the radiograph. It is mandatory that other tests be used in conjunction with radiographs. Figure 6-60 is a good case in point—a serious error in diagnosis avoided by additional films and vitality testing. In marked contrast, Figure 6-61 illustrates a tragic misdiagnosis owing to a singular dependence on radiographs. A simple vitality test would have alerted the dentist to an error in diagnosis.

Furthermore, it should not be assumed that a fistula is necessarily associated with the tooth to which it lies opposite. The draining sinus tract may arise some distance from its orifice. Radiographing a gutta-percha or annealed silver point along the length of the tract may totally change an initial snap diagnosis (Figure 6-62).

**Initial Radiograph.** Initial diagnostic radiographs must be studied carefully, not only as an aid in diagnosis but also as a “blueprint” for what to expect during treatment (Figure 6-63, A).

First, one must note the size and shape of the pulp chamber and the direction and angulation of the canals as they leave the chamber, as well as obstructions such as pulp stones. One realizes how valuable the initial radiograph is each time a tooth with a full crown is treated when the radiopaque metal crown eliminates a preview of coronal pulp anatomy.

Curvature of the roots and the approximate length of the tooth are next noted. Curvatures in the buccal or lingual directions are difficult to detect, but additional radiographic angulations may help. Distal or mesial inclination of the roots is usually apparent on the radiograph; that information can be used to prevent gouging and perforation of the root canals.

**Confirmatory Radiographs.** The radiograph is not only a valuable diagnostic tool, it is also an indispensable working tool. It provides pertinent information about treatment progress.

If, after the initial entry into the crown, the access opening appears to be headed away from the canal orifices, a confirmatory film should be taken to evaluate alignment (see Figure 6-11). Such progress films also provide assistance in searching for calcified canals.

The confirmatory length-of-tooth film is undoubtedly the second most valuable film to be taken after the initial diagnostic radiograph (Figure 6-63, B). In addition to information about the position of the file tip in relation to the root apex, it can also show whether the file is in the canal as intended or has entered a root perforation.

The confirmatory trial point radiograph serves two important purposes. First, it confirms the visual and “tugback” judgment of the fit of the initial filling point. Second, it provides the final opportunity to judge the advance of instrumentation. If an error in the length of the tooth has been made, and the canal has been instrumented short or long, here is an opportunity to correct the error.
Figure 6-58  Chronologic development of a suspected cementoblastoma over a 25-year period. A, Initial radiograph with a lesion apparent as a radiolucent area (arrow), as well as excess cemental formation. Note the huge pulp stone. The pulp is vital. B, Ten years later, a huge radiolucent lesion is present as well as a gross increase in cementoma. C, Fifteen years later, a decrease in radiolucency and an increase in cementoma. D, Twenty years later, virtual disappearance of radiolucency along with a gross increase in hypercementosis. E, Twenty-five years later, total cementoblastoma. The pulp remains vital. (Courtesy of Dr. Maurice J. Friedman.)
The confirmatory post-treatment film follows completion of the root canal filling. It should be made before a coronal restoration is placed because some correction in the canal filling may have to be made. Ideally, the final film for the record, and the duplicate film to be returned if a referring dentist is involved, should be taken without the rubber dam clamp (Figure 6-63, C).

Confirmatory progress films are also important during surgery. Searching for root tips, lost filling material, location of root apaxes during trephination or apicoectomy—these are only a few of the uses made of confirmatory radiographs.

Post-Treatment Evaluation Radiograph. Historically, post-treatment evaluations have been a part of clinical endodontic practice. This radiograph allows an opportunity to evaluate changes taking place periradicularly as a result of root canal therapy (Figure 6-63, D). A 1-year interval is a realistic time frame for most endodontic cases such as those with initial apical lesions or those with potential post-treatment problems. If any abnormal or unusual findings are noted, it may be necessary to re-treat, either surgically or nonsurgically, or if changes are uncertain, further re-evaluation may be indicated. Patients, however, may not consider post-treatment evaluation to be important, particularly if they are asymptomatic. Riley surveyed 159 diplomates of the American Board of Endodontics, who reported that fewer than half of their patients returned on recall.115

Re-treatment Radiography. Before initiating re-treatment, particularly a referred patient, the dentist must always have a “fresh film.” Films sent with the patient by the referring dentist may be outdated and may also have been taken prior to a procedure such as access preparation. A new film may supply surprising information about the tooth, perforations, broken instruments, failure to obturate, ineffective surgery, and a number of conditions well below the standard of care (Figure 6-64).
Figure 6-60  Importance of multiple roentgenographic exposures. A, Lateral incisor appears to be the principally involved tooth in this direct buccolingual projection. B, Projection through the central incisor shows that it is involved in the lesion as well. The lateral incisor is vital and the central incisor is nonvital, pulp death having developed from trauma (arrow). C, Following therapy, new bone develops throughout the area, and both teeth reattach. (Courtesy of Dr. Pierre R. Dow.)
Figure 6-61  Chronologic development of an internal resorptive defect that has become external as well. The patient is an adolescent female with bruxism (see chapter 4 and Figure 4–24). A, Mandibular incisors apparently involved with asymptomatic apical periodontitis. The pulps of both teeth are vital. B, The referring dentist mistakenly opened into vital pulp of the right central incisor. Detecting his error, he placed a temporary filling and dismissed the patient. C, Six months later, internal resorption from the stimulated pulp has perforated the root, and external resorption has also begun. D, Total pulpectomy, root canal therapy, and amalgam repair of the resorptive lesion save the incisor. The left central incisor remains vital. Alleviation of trauma from bruxism will allow healing.
Figure 6-62 Although the stoma of the draining sinus tract was over the canine pontic and the treated lateral incisor was suspected as the origin, it was actually the more distant central incisor causing the problem. (Courtesy of Dr. Cyril Gaum.)

Figure 6-63 Importance of initial and confirmatory radiographs. A, The initial film alerts the dentist to confusing canal anatomy and a significant periradicular and lateral root lesion. B, Confirmatory length of the tooth radiograph reveals the presence of a C-shaped canal. C, Immediate postoperative confirmatory film shows a complicated root canal system obturated by vertical compaction of warm gutta-percha. Obtura II was used for back-filling. D, Confirmatory 1-year follow-up film shows the degree of healing. (Courtesy of Dr. Michael J. Scianamblo.)
DIAGNOSTIC PERPLEXITIES

Even after a careful history and examination, some dental problems still defy immediate diagnosis. The most frequent among these have been cataloged as diagnostic perplexities: (1) sinus tract, (2) numbness, (3) persistent discomfort, (4) cracked tooth syndrome, (5) bizarre radiographic appearance, (6) idiopathic root resorption, and (7) treatment failures.

Sinus Tract

The stoma of a sinus tract may not always exist opposite the lesion. An example is the case of drainage in the area of an extracted canine (see Figure 6-62). Initially, the adjacent pulpless lateral incisor would be suspect. However, when a tracer gutta-percha point was inserted through the stoma to the depth of the sinus tract, it pointed to the pulpless central incisor. Harris revealed...
a pulpless maxillary central incisor that was draining extraorally through a stoma as far as the angle of the *ala nasi*\(^{116}\) (Figure 6-65). A similar situation, draining directly into the nostril from a periradicular lesion of a central incisor, was reported from Israel.\(^ {117}\)

Sinus tracts related to cracked teeth are most perplexing and often can be diagnosed only by the laying of a surgical flap. In one particular case, the fracture was not discernible in the initial radiograph, but following obturation of the root canal, the horizontal fracture became readily apparent (Figure 6-66).

**Numbness**

A symptom occasionally associated with endodontic cases is numbness in either the area containing the tooth or paresthesia of a distant part, such as the lip. When numbness occurs, one should also be concerned with trigeminal neuropathies—tumors or cysts that involve the innervation.

Numbness can also be related to large periradicular lesions encroaching on the mandibular canal (Figure 6-67, A). In this case, after root canal therapy, the numbness subsided, and within 14 months the lesion had healed and normal sensation had returned (Figure 6-67, B). Numbness associated with an acute alveolar abscess is often noted, but in such cases, the diagnosis should be quite obvious. Paresthesia may follow gross overfilling in the mandible, which invades the inferior alveolar canal. Paresthesia may also follow surgery in the region of the lower premolars.

Sixty-one cases of facial numbness were reviewed by researchers at the Mayo Clinic,\(^ {118}\) who found that 83% of the cases had a definite cause, including 48% in which the numbness was of dental origin. Thrush and Small reported seven cases of facial numbness, only one case of which was dental—typical mandibular numbness following a most profound local anesthesia and molar extraction.\(^ {119}\) The remaining cases of numbness were caused by carcinoma of the nasopharynx, tumor invasion of the gasserian ganglion, adenocarcinoma of the brainstem, and cerebrovascular accident. All of these patients exhibited numbness of the jaws, lips, tongue, or palate. They summarized their report by saying, “The most important task is to exclude neoplasia.” They recommended basal views of the skull and examination of the nasopharynx.\(^ {119}\)

**Persistent Discomfort**

After completion of treatment, either nonsurgical or surgical, some patients continue to have symptoms. Others develop discomfort some time later. A patient in the latter category was examined radiographically months after root canal therapy and placement of a bridge abutment. The discomfort was “midtooth,” and the radiograph revealed a bony lesion in that area along with external root resorption and a poorly obturated
midcanal (Figure 6-68, A). After re-treatment through the crown, the discomfort subsided (Figure 6-68, B). Failing root canal therapy appears to be one of the causes of post-treatment discomfort.

Glick reported a number of cases of persistent discomfort following root canal filling along with the bizarre symptom of continued sensitivity to cold. After careful examination ruled out the possibility of pulpitis in an adjacent tooth, Glick concluded that an additional canal must be present in the treated tooth, one that was missed during treatment. Reopening the pulp chamber and searching for the extra canal was not
productive. In desperation, Glick sealed formocresol in the chamber, which immediately and permanently eliminated the pain. Although not advocating this as a routine procedure, Glick has found it effective on a number of occasions.

In another report (Figure 6-69), cotton and Cavit (3M/Espe; St. Paul, Minn.) were sealed in a post-space preparation of a distal canal of a mandibular molar, resulting in continuous pain. When the post space was not used for the intended post and core, the space was refilled with gutta-percha and sealer. The cause of discomfort immediately became apparent when sealer was forced out of a minute fracture line.

In a most perplexing and life-threatening situation reported by Verunac, a young submariner consistently developed massive facial emphysema each time the submarine dived. The swelling would become pronounced after the submarine was deeply submerged for 15 hours (Figure 6-70). Within 4 or 5 days after surfacing, the swelling would disappear. Navy physicians had given him antibiotics to no avail and had recommended his discharge from the service. Examination by a dentist revealed a lingual cusp fractured away from a maxillary first premolar, exposing the lingual canal that was patent through the foramen. The air under submerged pressure was being forced through this tiny hole into the entire side of the face and neck (see Figure 6-70).

In a recent study, the phenomenon of barodontalgia (aka aerodontologia) was also reported during simulated high-altitude flights and in actual flights. Endodontically treated teeth or teeth with necrotic
pulps did not respond painfully in pressure chamber simulation. Only teeth with inflamed vital pulps reacted to pressure change.122

Another cause of persistent discomfort reported earlier in this text relates to root-filled teeth wherein the apex perforates a fenestration of the buccal bone. A similar report from Paris noted that the discomfort was relieved when the root end was exposed surgically and the portion of the root extending through the fenestration was “trimmed back” to within the bony housing.123

Cracked Tooth Syndrome

Infraction of tooth structure (cracked tooth syndrome) accounts for many perplexing diagnostic problems. A typical situation is that of a patient who experienced intermittent episodes of acute pain radiating over the entire side of the face. The periapical radiograph revealed a periapical lesion, and vitality testing proved the pulp to be nonvital. Before endodontic therapy was started, a bitewing radiograph was taken, revealing a vertical fracture into the pulp (Figure 6-71). It is interesting that the crack could not be seen in the periapical film but did show in the bitewing. Crown fractures, if in a buccolingual direction, may be more easily detected by bitewing radiographs.

Bizarre Radiographic Appearances

Radiographs have many limitations, one of which is that many conditions can produce similar appearances on x-ray films. Just such a case is illustrated in a film of a maxillary incisor. The tooth was exquisitely tender to percussion and was mobile. In the radiograph, a horizontal radiolucency appeared above the margin of the porcelain jacket crown (Figure 6-72, A), diagnosed as a fracture with pulp involvement. The crown was removed, and what appeared to be a fracture turned out to be a high chamfer crown preparation. This was verified with a second radiograph (Figure 6-72, B). The pulp was necrotic.

Idiopathic Tooth Resorption

It is difficult at times to determine the cause (or causes) for cases of root resorption. One such case involved the roots of a mandibular molar bridge abutment, where resorption began shortly after root canal therapy (Figure 6-73, A). Within 2½ years, the roots had completely resorbed away (Figure 6-73, B to D). One might speculate that this resorption could have been related to the patient’s breast cancer. It has been postulated that a parathyroid-like hormone is secreted by tumor cells, and there is a high incidence of hypercalcemia in patients with breast cancer.

Breast cancer could not have been an etiologic factor in a similar case reported by Poliak (personal communication, 1975). His patient was a middle-aged male motion picture producer who developed an unexplained resorption 5 years following therapy of an endodontically treated mandibular second molar. Within 2 years, the entire root structure had essentially resorbed away. From England, Pankhurst et al. reported a number of teeth in the same patient with idiopathic resorption.124

Treatment Failures

The examination of the treatment failures is important because if the cause of failure can be determined and corrected, the failure may be reversed.
Figure 6-72  A, Radiolucent line (arrow) is suspected of being a fracture under the jacket crown. B, The jacket crown is removed, and the “fracture” becomes a high chamfer preparation. (Courtesy of Dr. Cyril Gaum.)

Figure 6-73  Unexplained root resorption of bridge abutment in a patient with breast cancer. A, Initial film. B, One month later. C, Seven months later. D, Two and a half years later. (Courtesy of Dr. Cyril Gaum.)
Before proceeding with a detailed examination, the most obvious causes of failure should be eliminated: is the canal incompletely cleaned and filled, or, on the other hand, is there an obvious perforation of the root, obvious overfilling, or a crown or root fracture? If all of the obvious factors can be eliminated, then some other obscure cause of failure must be present. Remember, hoof beats usually means horses, not zebras!

The examiner should then begin a detailed examination following a four-stage procedure. One of these four steps in the examination should reveal the cause of failure:

1. Complete a thorough radiographic study of the involved tooth with exposure from three different horizontal projections, the standard buccal-to-lingual projection, 20 degrees from the mesial, and 20 degrees from the distal. The central beam must pass directly through the apex. If this does not reveal incomplete obturation of the apical one-third of the canal, a canal obviously not filled, a perforated canal, or an extra canal or root, then proceed to

2. Examine the involved tooth for signs of occlusal traumatism. Test the mobility of the tooth and, using the forefinger, test for movement under the forces of centric closure and both lateral excursions. Be certain to check the tooth for trauma in the non-functional, lateral position or “balance.” Look for telltale wear facets on occluding surfaces. If the tooth is not being traumatized by bruxism or an extraoral habit, then proceed to

3. Check the vitality of adjacent teeth to be sure that the periradicular lesion is not being maintained by an adjacent necrotic pulp. If all of these points of examination check out as normal, then

4. Check the involved tooth and adjacent teeth for a coexistent periodontal lesion. This step should be left until last because the area may have to be anesthetized to complete the periodontal probing to depth.

If all of these causes are checked and eliminated by examination, one may assume that failure is owing to an unusual factor such as a vertical root fracture or an incomplete root canal preparation and filling that does not show radiographically. If the unusual can be eliminated by careful questioning, observation, and examination, the examiner should finally suspect incomplete canal treatment, and steps should be taken to eliminate the cause.

Crump has summarized this very well, using the mnemonic device of POOR PAST, an acronym in which each letter stands for the failure to search for the following:

- **P** = Perforation
- **O** = Obturation incomplete
- **R** = Root canal overlooked
- **A** = Another tooth
- **T** = Trauma
- **P** = Periodontal disease
- **S** = Split tooth

By using the recall of POOR PAST as a check list, the clinician can go through all of the etiologic possibilities until finally arriving at the culprit. Unless the situation is hopeless, as with advanced periodontal disease or a vertical fracture, re-treatment will often reverse a failure into a success (see chapter 13). Occasionally, to get additional information, occlusal films or lateral head films are necessary to “reach” beyond the limits of the standard periradicular film. Teeth that “disappear” from traumatic intrusion may be shown on these films but off the scope of a periradicular film.

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