THE DENTAL CLINICS OF NORTH AMERICA

Dent Clin N Am 47 (2003) 605–621

Diagnostic modalities for infectious diseases

John A. Molinari, PhD

Department of Biomedical Sciences, University of Detroit Mercy, School of Dentistry, 8200 West Outer Drive, Detroit, MI 48219-0900, USA

The role of the microbiology laboratory is essential to successful provision of patient care. Appropriate, professional, and knowledgeable interaction with clinicians can especially benefit patients by achieving accurate diagnosis as promptly as possible and offers the clinician effective treatment approaches. Although the clinician's expertise is critical in distinguishing certain patient symptoms and signs, such as onset of localized swelling and patterns of fever and rashes in order to focus on a differential diagnosis, patients often present with very similar manifestations for infections caused by dissimilar microbial organisms. When coupled with the well-known observation that patient health histories do not always provide accurate or complete information for definitive diagnoses, the importance of the clinical laboratory in helping to determine a specific diagnosis and etiology cannot be underestimated. Obtaining appropriate laboratory data allows clinicians the best opportunity to arrive at a definitive diagnosis in a timely manner, eliminates the need for further tests, and can offer specific treatment approaches with maximal potential for success. In addition, accurate laboratory findings provide the clinician with valuable learned information for future cases with similar presentations.

Central to the laboratory's primary function of isolation and identification of microbial disease etiologies is the professional working relationship between the clinician, laboratory personnel, and infectious disease specialist should one be needed as a consultant. Scientific information applicable to disease diagnosis and clinical immunology is constantly expanding. It is therefore important for all of the professional participants to update their knowledge levels at frequent intervals so that they remain current with new in vitro techniques, reports of new isolated microorganisms, emerging

E-mail address: molinaja@udmercy.edu

doi:10.1016/S0011-8532(03)00059-4

infectious diseases, increasing antimicrobial resistance, and the myriad of taxonomic changes that accompany such advances [1].

The application of these clinical microbiology areas are essential for both medical and dental practitioners as they diagnose and treat an increasing variety of microbial diseases that are being diagnosed in an increasingly immune-compromised patient population. Much attention typically is focused on potentially catastrophic complications of medical infections, and yet errors in diagnosis and subsequent mismanagement of oral or maxillofacial infections also may lead to serious disease sequelae. Infections involving the oral cavity and other head and neck regions present the clinician and clinical laboratory with a variety of unique problems. These include the abundance of microbial forms present in the oral cavity, the changing nature of infections observed over recent years, and the increasing presence and colonization of antibiotic-resistant bacteria, viruses, and fungi in patients with histories of multiple infections and prolonged antimicrobial chemotherapy regimens.

An increasing percentage of the general population lives with a variety of acute and chronic conditions, which are unfortunately capable of compromising host immune defenses. The exhibited increased susceptibility of these individuals to a number of opportunistic microbial diseases mandates that any infectious process be effectively resolved as rapidly as possible, thereby preventing secondary, life-threatening complications. As a result of these types of patient occurrences, cooperation between medical and dental practitioners in interpreting and using information obtained from the laboratory is essential in accomplishing both therapeutic and preventive patient management.

The following brief overview attempts to apply the above general principles by considering the role of the microbiology laboratory in infectious disease diagnosis (extensive detail about specific tests and procedures can be found in many of the references cited). Emphasis is placed on laboratory procedures useful for diagnosis of oral or maxillofacial infections, with inclusion of the following areas: collection and transport of microbial specimens, representative techniques and methods available for culture and diagnostic assays, diagnostic laboratory principles for specific types of microbial etiologies, antimicrobial sensitivity, quality control issues, and evaluation of reported findings.

Collection and transport of microbial specimens

Collection of clinical specimens that are representative of infection etiology is fundamentally important to the success of laboratory analysis and disease diagnosis. Submitted tissues and fluids should be representative of the site of infection and provided in sufficient quantities for culture and microscopic observation [2]. Other important criteria applicable to specimen collection include the following.

Obtaining specimens whenever possible before the patient begins antibiotic chemotherapy

Even a single antibiotic dose can reduce microbial growth and thus decrease the chances of isolating appropriate organisms responsible for the infection. Ideally, cultures for analysis are to be taken before administration of any therapy that can affect the in vivo microbial flora. The presence of sufficient numbers of drug-resistant microorganisms in the sample also can skew the growth patterns of fastidious, slow-growing pathogens, especially in cultures that contain multiple genera and species. This consideration becomes especially important when there is a suspicion of anaerobic bacteria as the etiology because many genera require prolonged incubation periods (ie, 10–14 days) for suitable growth in culture. The more rapid growth of other organisms that can also be present in the specimen, such as staphylococci and certain streptococci, can readily mask the detection of the more fastidious, slower growing bacteria.

Use of proper swabs or containers during collection to ensure microbial viability during the intervals of transport to the laboratory and before the material is cultured and assayed after receipt

Although the most commonly used vehicles for specimen collection from intraoral and maxillofacial infections encountered in practice settings are cotton, rayon, Dacron, or calcium agitate–tipped swabs, these often are the least desirable devices because of their potential toxicity to collected organisms and their susceptibility to drying [3]. Fastidious organisms, including many of the strict oral anaerobic bacteria such as *Bacteroides*, *Fusobacterium*, *Prevotella*, and *Porphyromonas* species, often require special collection devices such as sterile syringes to collect fluid by way of needle aspiration. These can preserve microbial viability for hours after specimens are taken. Even brief intervals of exposure to oxygen can destroy most of the oxygen-sensitive organisms before laboratory analysis.

Application of blood cultures where appropriate

These cultures are most often used by clinicians in hospitals or other extended-stay health facilities and by oral surgeons obtaining specimens from deeper maxillofacial infections that are discontinuous with epithelial surfaces. A general principle for blood cultures is to collect samples when the patient's fever (if present) is peaking. Usually at this time, the concentration of organisms in the circulation is at a high level. When tissue sites are properly prepared with antiseptics before fluid collection, blood cultures can provide important information concerning the presence of even low numbers of invading microbes in the circulation.

Obtaining and submitting a smear of fluid material such as suppurative exudate on a glass microscope slide along with the protected material to be analyzed

This methodology allows the microbiologist to look at the host inflammatory response to infection and the characteristics of detected microbial forms at the time the sample was taken (Fig. 1). Information concerning the predominance of acute (polymorphonuclear leukocytes, neutrophils) or chronic (macrophages, monocytes, lymphocytes) inflammatory cells assists in better delineating the time frame of localized infections in addition to microscopically observing the types and relative presence of various bacterial forms. Table 1 summarizes microscopic features for representative observed bacteria in suppurative and chronic exudates.

Transport of specimens in containers sufficient to ensure maximal microbial viability and in a timely manner for initiation of laboratory analysis

Selection of a transport medium appropriate for the type of suspected microbial etiology and the site of infection is important for meeting this requirement. For example, most viruses collected in patient specimens do not survive well outside the body. Thus, special transport media suitable for viral forms to survive must be available in addition to routinely available

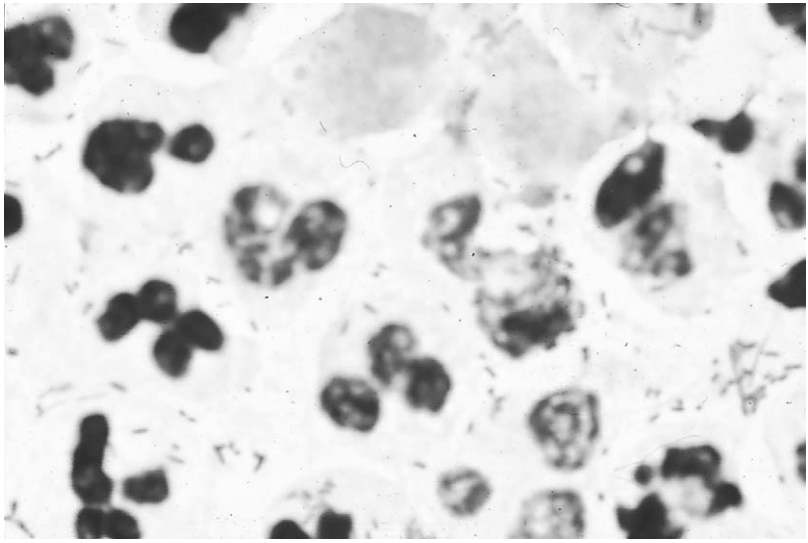

Fig. 1. Gram-stained preparation of suppurative exudate (pus) from a patient with an acute facial abscess. Note the predominant extracellular gram-positive rods and cocci throughout the specimen. Active phagocytosis also is evident by the extensive neutrophil population, and phagolysosomes can be seen. Many of these cells have readily visible multilobed nuclei. Few other inflammatory cell types are discernible (original magnification $\times 400$).

Table 1
Representative groupings of bacterial genera based on observations of gram-stained patient abscess smears

Microscopic description	Genera
Gram-positive cocci as single cells or irregular clumps	Micrococcus Peptococcus Staphylococcus
Gram-positive cocci as paired bacteria, or long or short chains	Enterococcus Lactococcus Pediococcus Peptostreptococcus Streptococcus
Large gram-positive rods	Bacillus Clostridium
Small gram-positive rods	Arcanobacterium Bacterionema Corynebacterium Eubacterium Lactobacillus Listeria Propionibacterium
Branching, filamentous gram-positive rods	Actinomyces Nocardia
Large gram-negative rods	Escherichia Klebsiella Proteus Salmonella Shigella
Thin, long gram-negative rods	Pseudomonas
Small, coccobacillary, gram-negative rods	Bacteroides Bordetella Capnocytophaga Eikenella Fusobacterium Haemophilus Legionella Porphyromonas Prevotella
Gram-negative cocci in pairs	Acinetobacter Moraxella Neisseria Veillonella

transport containers. With regard to bacterial specimens, two of the most common reasons for failure to obtain anaerobic bacterial growth in culture are a failure to preserve anaerobic conditions during specimen collection and failure to preserve microbial viability during transport to the clinical laboratory.

A summary of basic guidelines for collection and transport of representative specimens is provided in Table 2 [4]. Procedures for collection and transport of specimens from wounds or soft tissue infections can require special devices and materials. Although tissue samples usually yield the best results, they are often not available. The clinician should then attempt to obtain purulent fluid, preferably by aspirating material into a syringe to optimize the chances of culturing maximal numbers of aerobic, facultative, and strict anaerobic bacteria. Maintenance of sterility during collection, transfer into a secondary container, and transport is paramount during this process. The use of sterile swabs made of cotton or other materials as noted earlier is a commonly used, alternative method for infectious fluids. A number of commercially available culture kits contain both a sterile swab and transport medium contained in a glass ampule. After the swab containing the purulent specimen is placed back in the plastic transport tube, the ampule is squeezed and broken, effectively bathing the tissue fluid in a liquid transport medium. Systems using specific ampules containing carbon dioxide and hydrogen are especially important for the preservation of anaerobes during collection and transport to the laboratory.

To maximize the opportunity for obtaining a successful, useful microbial culture or assay specimen, effective communication between the clinician and clinical laboratory must occur. The text *Clinical and Pathogenic Microbiology* [3] provides a telling piece of advice to clinicians: "a poor specimen leads to poor results and possibly improper treatment of the patient."

Representative diagnostic techniques and methods

After specimens arrive at the laboratory, a number of general and specific methods are employed to identify microorganisms as rapidly as possible. A variety of microscopic, immunologic, microbiologic, and histopathologic tests can be employed to assist the clinician in arriving at both an initial and definitive diagnosis (Table 3). The most commonly used and rapid method of microbial analysis is the gram stain. Many different types of clinical specimens, including suppurative fluids, hemorrhagic exudates, blood smears, transudates, and tissue samples, can be easily processed using this classic staining procedure. Observed stained bacteria are classified as either gram-positive or gram-negative bacteria based on the concentrations of peptidoglycan and lipopolysaccharide components within the bacterial cell walls. Microscopic observation of gram-stained smears and tissues also provides information regarding microbial morphology (ie, cocci or rods; Fig. 2), and the arrangement/organization of isolated microbes (ie, parallel lines of rods, cocci in pairs, chains, or irregular clumps; Figs. 3, 4).

Subsequent identification of microorganisms typically occurs by using cultures having enriched nutrient–containing artificial media or by tissue

cultures. Bacteria are most often grown using appropriate in vitro agar plates or liquid media at 35–37°C, followed by observation of microbial colony morphology, sensitivity to antimicrobial agents, serologic tests, and assays with microbial biochemical tests characteristic of different microbial genera and species. Eukaryotic fungi, however, require less special processing of specimens, and are plated onto selective media containing antibiotics such as cyclohexamide, chloramphenicol, or gentamicin to inhibit bacterial growth and incubated at 30°C for extended periods up to weeks to culture suspected pathogens [4]. Sabouraud's agar is historically considered to be the general all-purpose medium for initial culture of most mycotic organisms, but a number of more highly selective media are available for isolation of specific genera.

With regard to culture of bacterial cultures from maxillofacial infections, among the most commonly used media are

- Thioglycollate broth or solid medium: able to provide sufficient environmental conditions to culture strict anaerobes such as *Bacteroides*, *Porphyromonas*, and *Prevotella* species.
- Blood agar enriched with 5% sheep blood: most commonly used all-purpose solid medium; allows for observation of beta- and alpha-hemolytic colonies resulting from synthesis of specific bacterial hemolysins; diagnostic medium for isolation and characterization of *Streptococcus pyogenes* from throat cultures taken from patients with bacterial pharyngitis.
- Chocolate agar: provides good conditions for growth of certain fastidious bacteria such as pathogenic *Neisseria*.
- Trypticase soy broth or agar: good all-purpose medium for growth of aerobes and facultatives.
- *Bacteroides* bile–esculin medium: observation of positive esculin reaction is presumptive for presence of bacteria in *Bacteroides fragilis* group.

In addition to noting the features of microbial colonies on selective media, specific biochemical tests offer opportunities to characterize microbial growth based on the cells' metabolism. In many instances, biochemical test kits are developed to assay for microbial enzyme products, and these have become increasingly sensitive. In certain instances, results provide a definitive identification of the primary infection etiology. One important bacterial example is the use of a coagulase test to look for the microbial production of this enzyme, which initiates formation of a fibrin deposit around *Staphylococcus aureus* colonies, thereby differentiating these from other staphylococcal species that may also be present but not involved in the infection. It is not the scope of this review to discuss the wide variety and importance of specific isolation media and identification techniques; therefore, the reader is referred to an excellent consideration of these areas for specific details [3].

Table 2
Collection and transport guidelines for Commonly submitted specimens

Specimen	Collection guidelines	Other comments
Abscess	Aspirate of pus or fluid in anaerobic transport vial preferred. Improperly collected swabs can have insufficient material for Gram stain and culture.	Specimen sent immediately in syringe is also acceptable, but without a needle attached.
Biopsies	Keep specimen moist and transport rapidly to lab. Biopsied specimens are suitable for fungal, mycobacterial, viral, and anaerobic cultures, depending on the site of biopsy.	Always specify the type of tissue and indicate the specific pathogen sought if other than routine bacteria (eg, *Nocardia, Bartonella, Histoplasma*).
Blood	Prepare site with 70% alcohol, then with an iodophor. Cleanse top of culture bottles/tubes with 70% alcohol; do not change needles to inoculate.	All blood cultures should be transported as soon as possible to start incubation or processing.
Anaerobes	If anaerobic bottle is not part of laboratory's routine culture set, contact laboratory for instructions.	
Respiratory, upper		
Nose	Anterior nares swabs usually submitted only for detection of staphylococcal or Streptococcal carriers.	Use bacterial transport media; specify organism.
Nasopharynx	Nasopharyngeal specimen appropriate for *Bordetella pertussis, Corynebacterium diphtheriae, Neisseria gonorrhoeae, Neisseria meningitidis*.	Cough plates for pertussis are not recommended; use calcium alginate swabs and plate directly or send quickly to laboratory.
Oral cavity	Swabs or scrapings taken from oral lesions.	
Bacteria	Not usually cultured, but direct smears may be used to demonstrate fusospirochetal disease.	
Fungi	Gram stain, Calcofluor white stain, or KOH preparation can be used for direct detection of yeast. Culture not generally done unless identification or susceptibilities of yeast are wanted.	Follow laboratory guidelines for submission of samples for direct smears.

Throat	Swab areas of purulence or ulceration. Notify laboratory if looking for organism other than group A streptococci.	Use transport media.
Sputum		
Bacteria	Sputa are screened for acceptability by absence or low numbers of squamous epithelial cells in the presence of neutrophils. Not suitable for anaerobic culture.	Expectorated sputa may not be best specimen for diagnosis of bacterial pneumonia. Concomitant blood cultures are recommended.
Mycobacteria	First, early-morning specimen is preferred, not pooled. Should not be screened for adequacy. Send 3 consecutive first morning specimens for optimal diagnosis.	
Fungi	Should not be screened for adequacy. Send 3 consecutive first morning specimens for optimal diagnosis. Induced sputum recommended for *Pneumocystis*.	If known, specify particular agent of concern, (eg, *Cryptococcus Histoplasma, Nocardia*, and so forth). Isolation of *Candida* spp. from sputum is not diagnostic of *Candida* pneumonia.
Skin scrapings for dermatophytes	Scrape skin at active edge of lesion; avoid blood. Place in sterile petri dish.	
Skin lesion	Specimen taken from advancing edge is recommended. Biopsy may be more definitive than swabs of lesion. Appropriate for routine, fungal, and mycobacterial culture.	Transport swabs in transport media to prevent drying out.

Adapted from Gill VJ, Fedorko DP, Witebsky FG. The clinician and the microbiology laboratory. In: Mandell GL, Bennett JE, Dolin R, editors. Principles and practice of infectious diseases. Philadelphia: Churchill Livingstone; 2000. p. 187–188; with permission.

Table 3
Representative laboratory methodologies for diagnosis of infectious diseases

Type of test	Comments
Microscopy	
Electron microscopy	Useful for detecting viruses. Specific antibodies may be added to patient specimen to enhance chances of visualizing viruses present.
Brightfield microscopy	Used for determination of presence of acute or chronic inflammatory cells, along with visualization of bacteria, yeasts, fungi, or other microbes.
Darkfield microscopy	Useful for observation of spirochetes in fluid and biops tissue specimens.
Fluorescent antibody microscopy	Fluorescein isothiocyanate–labeled conjugated antisera is useful for detection of certain bacteria and fungi.
Phase contrast microscopy	Used for observation of living cells and inclusion bodies in viral-infected tissue specimens.
Immunology and serology	
Specific antibodies	Used for highly sensitive detection and measurement of antibodies produced against invading bacteria, fungi, mycoplasma, and viruses; in the case of viral infections, this methodology is most often easier than isolation of etiologic organisms.
Antigen detection	Direct, sensitive detection method that tests for a number of bacterial and fungal antigens using agglutination or enzyme immunoassays.
Lymphoid cell detection and activity	Used for determination of CD4+ Th1 and Th2 cells and other lymphocyte classes based on surface membrane markers; production and activity of cytokines, lymphokines, and specific interleukins.
Complement activity	Used for quantification of serum complement components; evaluation of deficiencies in individual complement factors, that can be associated with patient susceptibility to certain infectious pathogens.
Microbiology	
Gram stain	Basic test for determining gram stain response of organisms (gram-positive or gram-negative); useful for detection of cocci and rods in specimen; allows for observation of single or multiple microbial types in specimen and culture.
Special stains	
Ziehl–Neelsen	Good general stain technique used for identification of acid-fast mycobacteria on direct specimen smears or with cultured organisms; also, a modification of the technique is useful for identification of *Cryptosporidium* in contaminated acqueous samples.
Acridine Orange	Available test for visualization of certain bacteria that may not be readily observed with gram stain, such as *Mycoplasma* species, and for differentiating bacteria from human cells in collected samples.
Gimenez and Dieterle silver	Used for detection of *Legionella* species.
Gomori methenamine–silver nitrate	Used for observation of mycotic organisms in yeast or fungal forms; visualization of *Pneumocystis carinii*.

Table 3 *(continued)*

Type of test	Comments
Periodic acid–Schiff	Used for observation of mycotic organisms.
Malachite green	Used for detection of bacterial spores.
Anthony/Hiss	Used for demonstration of polysaccharide capsules surrounding bacteria.
Leifson	Used for detection of motile bacteria by staining of flagella.
Wet mounts	A method suitable for observation of fungi.
Culture and antibiotic susceptibility	Used for identification of species and determination of antibiotic susceptibility.
Culture tissue specimen	Used in the culture of microorganisms that are difficult to culture from acute abscess fluids.
Cell cultures	Technique allows detection of many viruses and other organisms that cannot be cultured using *in vitro* methodologies.

To provide the clinician with as much pertinent information as possible for diagnosing and treating an infection, laboratory cultures are also set up to assay for patterns of sensitivity and resistance to antimicrobial agents. This important analysis can be done by using paper discs impregnated with a known concentration of individual antimicrobials that diffuse out into the solid agar culture during incubation, leading to a zone of inhibition around discs where microbes were prevented from growing (Fig. 5), or with more quantitative dilution techniques using microtiter plates and liquid microbial

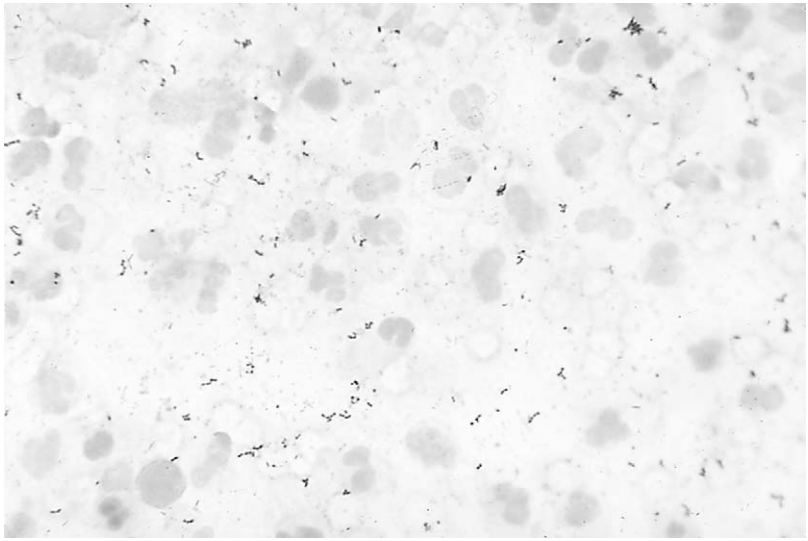

Fig. 2. Detection of gram-positive staphylococci in exudate from a mandibular abscess (original magnification ×400).

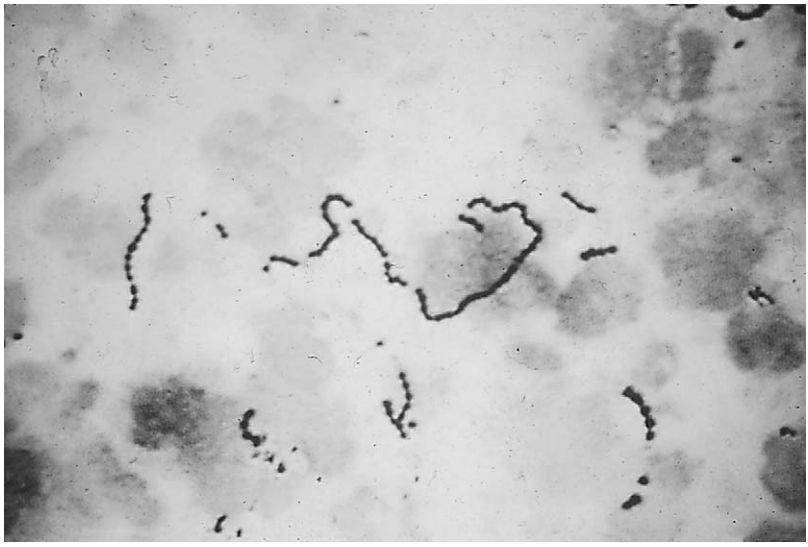

Fig. 3. Gram-positive cocci in chains, latter characterized as group A, beta-hemolytic, *Streptococcus pyogenes* in pharyngeal exudate from a patient with pharyngitis (original magnification ×400).

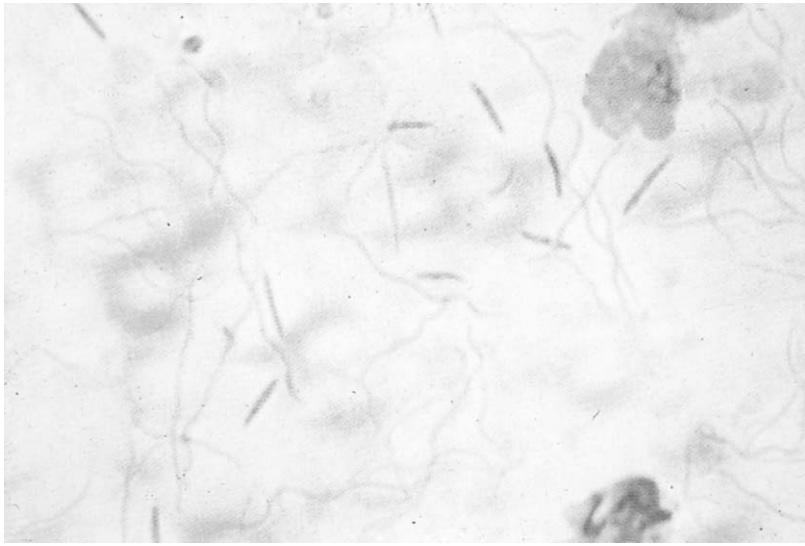

Fig. 4. Anaerobic, cigar-shaped fusobacteria and spirochetes stained in a smear taken from a patient with necrotizing ulcerative gingivitis (original magnification ×400).

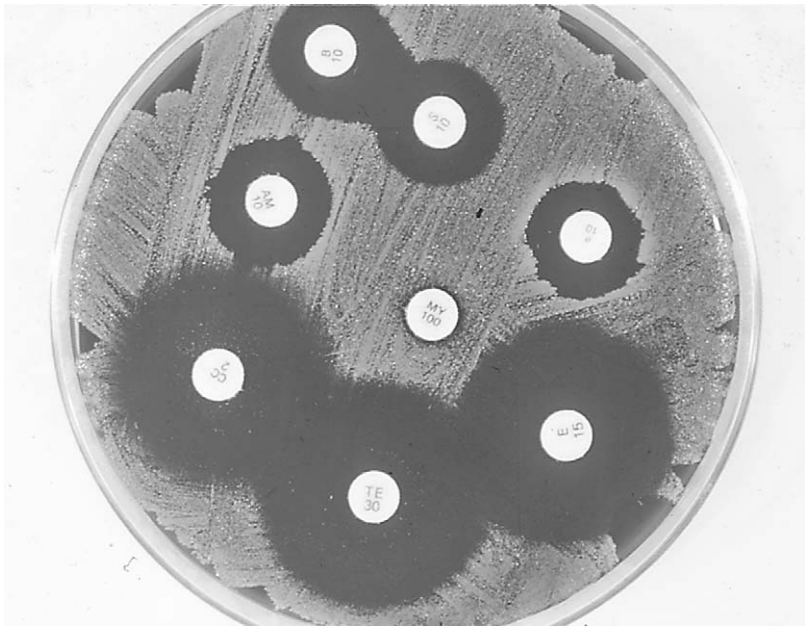

Fig. 5. Use of antibiotic-impregnated paper discs to determine sensitivity pattern of cultured bacteria.

cultures initially mixed with increasing concentrations of antimicrobial agents. The steady rise of resistant bacterial, fungal, and viral strains in patient infections has caused a dramatic shift in how and when antimicrobials are used during patient care. Penicillin resistance, for example, has become commonplace among many bacterial genera, along with a noted decreased efficacy of other antibiotics, as a variety of pathogens found in many medical and dental infections have acquired partial or complete genetic resistance to many life-saving agents [5–11]. Demonstration of resistance against antiviral agents in the management of viral disease requires modification of the above approaches. This form of microbial resistance is defined as a decrease in the viral susceptibility to an antimicrobial as established by in vitro assay and confirmed by genetic analysis of the viral genome and biochemical analysis of the altered viral enzymes [4,12].

Many of the above discussed methodologies and tests have been developed and refined for identification of bacteria but are not applicable in the search for viruses. Other additional approaches are therefore used to isolate and characterize these microbes in clinical specimens:

- Microscopic cytolytic changes in infected cell cultures: characteristic cytoplasmic or nuclear inclusion bodies can often be seen within 24 hours as a result of certain viral infections.

- Polymerase chain reaction: this rapidly expanding diagnostic method can use a few copies of viral DNA and amplify them many thousand fold to attain sufficient levels for detection by the laboratory.
- Serology: immune assays are commonly used in the diagnosis of viral infections, using tests to detect and quantify viral antigens and, later, synthesis of specific antibodies during the course of infection and recovery. Continued advances in serology and immunochemistry have allowed increased routine, successful use of these types of in vitro techniques because they are easier to perform than isolating the causative virus.

Reporting of results and laboratory evaluation

Despite the best efforts of the clinician and laboratory personnel to collect, transport, and process specimens under optimum conditions, a number of problems can still arise. In the case of specimens obtained from intraoral and other head and neck infections, these problems often involve procedures designed to culture and isolate bacterial etiologies. Table 4 summarizes a few common problems that may occur and require recognition and ultimate resolution [13].

In certain instances, a provisional or suspected diagnosis can be made rather quickly from staining smear preparations from an infected site and looking at them under a microscope. More definitive information may not be obtained, however, until the next day after specimens are collected, transported, and processed. Multiple factors may delay laboratory personnel from providing the clinician with definitive results, even when procedures are appropriately followed by the two professional parties:

- The patient specimen may contain only a few organisms, thus requiring intervals of a few days or longer for microbial replication to reach detectable concentrations.
- Certain microorganisms such as strict anaerobic bacteria grow slowly in enriched media, even under the best of anaerobic conditions. Definitive microbial information transmitted to the clinician may therefore be delayed for up to 2 weeks. In this type of case, the clinician is required to use his or her best clinical judgment by using all available findings along with his or her experience, and from communication with the laboratory microbiologist, to continue patient therapy until final results are reported.
- There are some bacteria that require even longer culture intervals. Included here are some mycobacterial species that grow very slowly, and may take up to 6 weeks to provide visible colonies in vitro. Fortunately, major efforts have been directed at developing more rapid identification assays for these acid-fast bacteria, with particular emphasis toward isolation of *Mycobacterium tuberculosis* from suspected patient sputum samples [14–16].

Table 4
Common problems associated with processing bacterial cultures

Problems	Solution to problems
Failure to obtain suitable clinical material	
Premature attempt to collect specimen	Submit sterile saline solution injected and withdrawn from involved area. Wait until fluctuance develops.
Incorrect placement of needle for collection of specimen	Reassess infection site and aspiration. Verify presence of fluctuance.
Failure to obtain laboratory growth	
Failure to preserve anaerobes during specimen collection	No viable organisms were present. Results are valid. Use anaerobic collection devices (aspiration with syringe or anaerobic swabs.
Failure to preserve vitality during transit to laboratory	Use anaerobic transport media and method. Transport specimen more rapidly to laboratory.
Failure of laboratory to correctly manage specimen	Contact laboratory to discuss their management of the specimen. Verify their procedure to manage anaerobes.
Laboratory reports normal oral flora	
Salivary contamination of specimen	Review collection technique. Collect new specimen under moreaseptic conditions. Remember that most odontogenic infections arise from ''normal oral flora''.
Laboratory did not perform detailed identification	Inform laboratory of need to be more specific as to dominant species and to do antibiotic susceptibility tests on those.

Adapted from Hohl TH, Whitacre RJ, Hooley JR, et al. A self-instructional guide: diagnosis and treatment of odontogenic infections. Seattle (WA): Stoma Press; 1983. p. 147; with permission.

Results sent from the laboratory to the clinician should contain enough information to provide re-evaluation and, it is hoped, re-enforcement of patient therapy currently underway. Depending on the type of original patient sample, information reported may include macroscopic appearance of collected specimens; microscopic interpretation of exudate smears or tissue biopsy specimens from infection sites; culture data and microbial identification from microbial growth on selective media or tissue culture and definitive biochemical tests; antimicrobial sensitivity patterns; serologic analysis using detection of microbial antigens and specific patient responses; and findings from other appropriate rapid assays such as polymerase chain reaction, recombinant DNA assays, and molecular-based probes.

Evaluation of the laboratory and its personnel must be an ongoing process. Adherence to regulatory requirements and standards must be stringently enforced. Periodic re-evaluation and updating of policies and procedures is essential not only in assuring clinicians that submitted specimens are analyzed using the best possible techniques but also because it

requires the laboratory personnel to continue to keep up with emerging technologies. In addition, participating clinicians should also be informed of laboratory policies and guidelines for specimen submission. As important as each of these and other measures not mentioned are, the ultimate clinical success of the microbiology laboratory is dependent on the extent of interaction with other involved health professionals [4]. Good communication, sharing pertinent guidelines and information, and being rapidly responsive to clinician and, ultimately, patient needs will maximize the potential for earlier infection diagnosis and better management.

References

[1] Pfaller MA, Herwadlt LA. The clinical microbiology laboratory and infection control: emerging pathogens, antimicrobial resistance, and new technology. Clin Infect Dis 1997;25:858–70.
[2] Bartlett RC. Laboratory diagnostic techniques. In: Topazian RG, Goldberg MH, editors. Oral and maxillofacial infections. 3rd edition. Philadelphia: W.B. Saunders; 1994. p. 79–111.
[3] Rubin SJ. Specimen collection and processing. In: Howard BJ, Klass J II, Rubib SJ, Weissfeld AS, Tilton RC, editors. Clinical and pathogenic microbiology. St. Louis (MO): C.V. Mosby; 1987. p. 207–30.
[4] Gill VJ, Fedorko DP, Witebsky FG. The clinician and the microbiology laboratory. In: Mandell GL, Bennett JE, Dolin R, editors. Principles and practice of infectious diseases. Philadelphia: Churchill Livingstone; 2000. p. 184–221.
[5] Heimdahl A, von Konow L, Nord CE. Isolation of B-lactamase-producing *Bacteroides* strains associated with clinical failures with penicillin treatment of orofacial infections. Arch Oral Biol 1980;25:689–92.
[6] Edson RS, Rosenblatt JE, Lee DT, et al. Recent experience with antimicrobial susceptibility of anaerobic bacteria. Mayo Clin Proc 1982;57:737–41.
[7] Doern GV, Ferraro MJ, Brueggemann AB, et al. Emergence of high rates of antimicrobial resistance among viridans group streptococci in the United States. Antimicrob Agents Chemother 1996;40:891–4.
[8] Lundstrom TS, Sobel JD. Antibiotics for gram-positive bacterial infections. Infect Dis Clin N Am 2000;14:463–74.
[9] Berkowitz FE. The gram positive bacilli: a review of the microbiology, clinical aspects, and antimicrobial susceptibilities of a heterogeneous group of bacteria. Pediatr Infect Dis 1994;13:1126–38.
[10] Lee YC. Laboratory testing of newer antibiotics against gram-positive organisms: avoiding false susceptibility and resistance results. Clin Microbiol Newsl 2003;25:9–16.
[11] Steward CD, Wallace D, Hubert SK. Ability of laboratories to detect emerging antimicrobial resistance in nosocomial pathogens: a survey of project ICARE laboratories. Diagn Microbiol Infect Dis 2000;38:59–67.
[12] Swierkosz EM, Biron KK. In: Murray PR, Baron EJ, Pfaller MA, et al, editors. Manual of clinical microbiology. 6th edition. Washington, DC: American Society for Microbiology; 1995. p. 1415–23.
[13] Hohl TH, Whitacre RJ, Hooley JR, et al. A self-instructional guide: diagnosis and treatment of odontogenic infections. Seattle (WA): Stoma Press; 1983. p. 147.
[14] Della-Latta P, Weitzman I. Mycobacteriology. In: Isenberg HD, editor. Essential procedures for clinical microbiology. Washington, DC: American Society for Microbiology; 1998. p. 169–203.

[15] Roberts GD, Bottger EC, Stockman L. Methods for the rapid identification of mycobacterial species. Clin Lab Med 1996;16:603–15.
[16] Witebsky FG, Kruczak-Filipov P. Identification of mycobacteria by conventional methods. Clin Lab Med 1996;16:569–601.