A REVIEW AND RETROSPECTIVE STUDY OF SOME
MAJOR BACTERIAL OROFACIAL INFECTIONS

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A THESIS SUBMITTED IN PARTIAL REQUIREMENT
FOR THE DEGREE OF MASTER OF DENTAL SURGERY

DEPARTMENT OF ORAL MEDICINE AND ORAL SURGERY,
FACULTY OF DENTISTRY
UNIVERSITY OF SYDNEY
1990
PREFACE

History has recorded the antiquity of serious infections in the region of the head and neck. Today, our community still experiences major life-threatening infections in these anatomical locations, which pose significant management difficulties to the oral and maxillofacial surgeon. The aim of this thesis is to review the aetiology, diagnosis and treatment of some bacterial infections involving structures of the head and neck. Such infections may spread, causing serious complications with severe morbidity and occasionally death. This thesis deals only with infections of bacterial origin and does not attempt to cover viral, or fungal agents or the chronic specific diseases of tuberculosis and syphilis, and makes no attempt to address the old question of focal infection.

The literature review relates especially to Ludwig's Angina which was first described so dramatically in 1836. To this day it remains as a clinically potentially lethal disease despite the progress of modern medicine. Numerous descriptions in the literature warn of the rapid appearance of symptoms and the danger of respiratory obstruction when management of the airway is not satisfactorily undertaken. Both odontogenic and non-odontogenic causes of orofacial and neck infections are reviewed. Odontogenic problems are given special emphasis as they are now of major concern. The significance of the potential fascial spaces in the face and neck which allow the spread of dental infections is also highlighted. A thorough knowledge of these anatomical relationships is still of the utmost importance to the surgeon if he is to be successful in treatment. The principle of surgical drainage of pus is as important in 1990 as it was 150 years ago.

The biological basis for the onset and progress of such fulminating infections in the head and neck region is still poorly understood. One
constant need is that the bacteria, both aerobic and anaerobic, be correctly identified. Microbiological techniques are constantly improving and provide an important adjuvant investigation, which then allows the surgeon to provide the most appropriate antimicrobial therapy.

Principal to the many aspects of treatment is the ability to maintain the airway of the patient and to provide the depth of anaesthesia necessary to undertake the required surgery.

Major bacterial orofacial infections may have severe local and far-reaching systemic effects. Such complications are discussed in all their ramifications. It should be realised that the presentation of these patients at a late stage, when complications have already supervened, may make diagnosis difficult. There is always a necessity to ensure that the underlying cause of the disease is accurately defined and that complications are not allowed to progress further.

Finally, a retrospective study of the management of 90 patients with major bacterial orofacial infections who have been treated at Westmead Hospital is presented.

The outcome of this study of some major bacterial orofacial infections of the head and neck is the need to stress the importance of urgent surgical management and maintenance of the airway, together with the microbiological determination of the causative organisms and their sensitivities, so that other than empirical antibiotics can be instituted early. This must be combined with an upgrading of the patients' medical and dental status.

It was demonstrated that, in the majority of these patients, ignorance and fear combined with a lack of routine dental care resulted in major infections arising from relatively simple odontogenic causes such as dental caries, periodontal disease and pericoronal infection related to impacted teeth. Without doubt, the immediate care of these patients demanded
intensive management. However, it is important to recognise that dental education forms an integral part not only of the recovery programme for the afflicted patient, but also as a community health preventive measure of profound significance.
ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to my supervisor, Associate Professor G. C. Stacy, and to Dr. G. M. W. McKellar, without whose constant support and encouragement this thesis would never have been completed.

I am also grateful to:

Doctors McKellar and Rengaswamy and other members of the Consultant Surgical Staff of the Westmead Hospital for allowing me to present their patients.

Associate Professor N.H.H. Smith, Professor M. M. Ferguson and Dr. T. Voss for reading and providing suggestions to the Thesis.

Dr. Rosemary Munro and members of the Bacteriology Department at the Westmead Hospital for providing the microbiological data.

Mr. John E. de B. Norman for providing photography of the patient with cavernous sinus thrombosis.

Mr. Bill Booth for his critiquing and proof reading of the manuscript.

Mrs. Athena Webster for the unenviable task of typing and re-typing the manuscript.
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CHAPTER 1

LITERATURE REVIEW
1.1 Introduction

This literature review is concerned with accounts of orofacial and neck infections from early times through the pre-antibiotic era of the twentieth century to the current antibiotic age. It is of both historic and clinical interest to follow through these times the changes in presentation, the improvement in diagnosis, and the developments in microbiology and antimicrobial chemotherapy, together with the changes in outlook towards the surgical and airway management of such patients.

1.2 Ancient History

The Greek and Arab authors (Parker 1879 and Muckleston 1928) gave vivid descriptions of diseases which produced dramatic inflammation of the mouth, tonsils and larynx. As the chief symptom was a sense of suffocation the Greek term of "cynanche" was applied which literally meant "dog choking". This term later passed into Latin and then old French as "siquancie" and thence into English as "squinancy" a form now obsolete, and finally reached us as "quinsy" (Muckleston 1928).

It was realised that if the infection spread to the chest, the patient would inevitably die of respiratory difficulties. However, if abscess formation occurred either intra- or extra-orally which allowed drainage to occur spontaneously, there was a possibility that the patient might survive. Surgical intervention was recommended by such physicians as Paulus Aegineta and Hippocrates; the latter advocated opening the veins below the tongue (Parker, 1879). Thus, the two most important principles in the management of such major infections of the head and neck - the ability to maintain a patent airway and the drainage of infection - were already appreciated. These principles are of paramount importance in modern medicine today and still form the basis of our management of such afflicted patients.
1.3 18th Century

Prior to Ludwig the occurrence of "cynanche" was described by Colden in New York (1735), and by Fothergill (1739-1746) in his "Account of Putrid Sore Throat", and was observed by Cholmer (1770) in South Carolina and by Kirkland (1786). The Spaniards called it "garotillo" (after "garote", a loop used by hangmen) and the French called it "l'esquinancie inflammatoire gangrenouse" (Deberge, 1758) or "phlegmon largeseducon" (Dupuytren, 1833). Of note, General Washington is reputed to have succumbed to a haemorrhage caused by "cynanche trachealis" in 1799 (Muckleston 1928).

In 1789 Stratton, who based his work on the teachings of the Scottish physician, William Cullen, attempted a classification of "cynanche" into five species:

- cynanche *tonsillaris* which included simple tonsillitis and quinsy;
- cynanche *maligna* which covered faucial and pharyngeal diphtheria;
- cynanche *trachealis* which meant croup and laryngeal diphtheria;
- cynanche *pharyngea* which was simply an extension of a tonsillar infection to the pharynx;
- cynanche *parotidea* which was definitely mumps as it included a description of the involvement of the ovary and testicle

1.4 Ludwig: 1836

It is probable that severe odontogenic infections would have been included in the subspecies "cynanche tonsillaris" and "pharyngea". In 1836 Wilhelm Frederick von Ludwig described his observations concerning repeated occurrences of an inflammation of the throat, which, despite the most skilled therapy known at that time, was usually fatal. Thus, the most severe of orofacial infections was described as "Ludwig's Angina" (Burke 1939). The word angina comes from the Latin "angere" meaning to strangle or to suffocate.
Ludwig described the important features and course of the disease as beginning with general systemic changes:

- temperature swings with frequent chills
- headache
- fatigue
- disturbed appetite
- slightly coated tongue
- discomfort upon swallowing

and then the development of local changes:

- a firm unilateral or bilateral swelling in the neck around the submaxillary glands but occasionally involving the parotid or sublingual glands,
- then the spread of this firm, connective tissue "tumefaction" under the jaw to the chin and the larynx and backwards over the tissues of the parotid,
- then spreading to involve the muscles between the larynx and the floor of the mouth so that the tongue rests upon a red indurated mass which feels like a hard ring adjacent to the inner surface of the jaw bone.

At that stage there would be:

- difficulty and pain on attempting to open the mouth,
- speech impairment of a hoarse and throaty quality,
- difficulty in swallowing.

The progress of the disease would lead to the skin over the induration becoming red and with certain areas both extra- and intra-orally becoming softer, suggesting that suppuration began and then stopped; this would be associated intra-orally with a foul discharge of a light grey or reddish-brown fluid.

The general status of the patient would be grossly affected by this septic process with:
- increase of fever
- fitful sleeping
- profuse sweating
- urine showing a heavy sediment
- nightmares and mild deliriums
- swallowing continuing to be difficult
- continued inability to open the mouth
- dyspnoea appearing usually in paroxysms

In 4 to 5 days (the 10th to 12th day of the disease) death would occur with the patient in a comatose state with evidence of respiratory paralysis.

Ludwig carried out autopsies on some of these patients. His findings noted that the skin and subcutaneous tissues, which were separated from the underlying muscles, were themselves unchanged as were the salivary glands. However, the muscles of the affected areas showed varying degrees of degeneration in which abscess cavities occurred. One of the most distinctive features of the disease was the loosening of the periosteum from the bone. Intra-oral examination showed reddening of the mucosa of the tongue, pharynx and trachea. This mucosa was also loosened from its underlying tissues.

Ludwig reported that slight improvement could occur briefly with therapy which included: local and general blood letting, softening poultices and cataplasms, external and internal use of mercurials, relief of spasm by the remote application of sinapisms and vesicants, cathartics, diuretics and diaphoretics. However, the disease usually progressed unhindered in its systemic manifestations and ended fatally as Ludwig had described. Ludwig named this infection a "gangrenous induration of the connective tissues of the neck" and surmised that the cause may be an erysipelatous lesion, which was checked in its surface spread, and was forced into deeper tissues where it underwent transformation into a gangrenous inflammatory connective tissue.
induration.

Ludwig's presentation appeared as a leading article without a title in the Wurtemberg's Medical Journal in 1836 being one of only two articles that he contributed to the medical literature. Ludwig practised in Stuttgart from 1817 till his retirement where he was active in internal medicine as well as in surgery and obstetrics. He was particularly renowned for his keen diagnostic ability, and following the publication of his paper concerning the gangrenous induration of the connective tissues of the neck, considerable interest was shown and an increasing number of patients with fulminating neck infections were reported. It was only in the following year, 1837, that Camerer applied the name: Ludwig's Angina (Muckleston 1928). Though the literature has repeatedly suggested that the terminology is inappropriate and should be changed this has never occurred, and today, Ludwig's Angina is still used to describe the major bacterial orofacial infection which simultaneously involves the sublingual and submandibular spaces bilaterally.

1.5 19th Century

The rapid spread of this infection in patients was the most significant feature recorded by the other 19th century authors (Von Thadden 1872; Doig 1876; Stuart 1879; Parker 1879; Roser 1883; Koenig 1882; Croly 1883; Younge 1884; Barker 1885; Poulsen 1886; Gibson 1893; Lockwood 1895; Fenwick 1897; Phillips 1898; Webber 1898). Virtually no treatment was available apart from the application of fomentation and, in the later stages, drainage. Sometimes spontaneous drainage would occur; otherwise incisions were made in the neck to divide the cervical fascia and allow discharge of blood and pus (Croly 1883). Before operating, the "lines of safety" and the "lines of danger" were established in the neck (Figure 1). The lines of danger being in the direction of the external jugular vein passing from the angle of the jaw downwards and outwards across the sternomastoid muscles, and also
FIGURE 1. Neck Incisions (Croly 1883)
correspond with the carotid artery in its course upward and backward.

It was suggested that in making the incisions it was best to adopt the method recommended by Hilton-viz. to make an incision through the skin with a scalpel and then, having passed an ordinary pair of dissecting forceps through the cervical fascia, forcibly separate their blades and thus tear through this structure (Muckleston 1928).

It was also appreciated that predisposing conditions which tended to lower the general health of the patient were of significance. For example:
- lack of attention to hygienic conditions
- intemperance
- malnutrition
- the opposite extreme of overfeeding combined with a lack of exercise
- diseased states of the blood

The actual cause of the disease was considered to be a "damaged spot within the cavity of the mouth or throat" (Barker 1885). Barker was particularly aware of the dangerous nature of the spread of infection and supported early surgical intervention to obtain drainage and the use of beneficial tonics for the patient.

Other observations in the late 19th century gave recognition to the synergism of aerobic and anaerobic organisms in the aetiology of orofacial infections. Lockwood (1895) described a patient with Ludwig's Angina who died of bacillary septicaemia in which he demonstrated a "large bacillus" present in the deep muscles and tissues of the floor of the mouth and neck. Lockwood felt these bacilli were important because Ludwig’s Angina resembled an acute spreading gangrene, a disease acknowledged to be of bacillary origin.

It appeared that tracheostomy together with wide surgical incisions represented the only chances of survival for many of these afflicted
patients. Phillips (1898) and Webber (1898) described patients who underwent these procedures and particularly noted the difficulty of performing the tracheostomies when oedema displaced the trachea.

Towards the end of the 19th century the French Surgical Society held several meetings devoted to the discussion of Ludwig's Angina. The group led by Delorme gave Ludwig's Angina its proper place in surgical pathology stating that it was primarily a sublingual phlegmon. This was supported by a thesis written by one of Delorme's students, LeTerrier, in 1893.

In 1886, Poulsen had demonstrated the spread of infection in the neck by a series of lime injections under the deep fascia of the neck, which proved the existence of communicating channels of loose connective tissue between the various adjacent interfascial spaces. Later in 1893, he reviewed 530 neck abscesses collected from hospital statistics which supported his hypothesis, that infections would follow these channels and invade the various spaces.

Moty (1892) had a good understanding of the spread of infection stating that a dentoalveolar abscess in the mandible could point toward the skin or buccal mucosa, but when the process was acute, infection could first make its way into the sublingual tissues or towards the tissues surrounding the great vessels of the neck.

So, by the end of the 19th century, major orofacial infections involving the mouth, throat, neck, submandibular and parotid regions, which were clinically known as Ludwig's Angina had been described. They were recognised as septic infections which had a rapid onset of development and were attended by severe symptoms and a high rate of mortality. Management was concerned with maintaining the airway by tracheostomy and with the application of the surgical principle of incision and drainage of the infection.
1.6 Davis 1906

Though Ludwig had been able to recognise orofacial infection as being of septic origin, he was limited to his clinical observations and gross post-mortem examinations, as the science of bacteriology was practically unknown in 1836. Davis (1906) realised that in order to provide efficient treatment, the pathology of the disease must be fully understood. If the pathology of a disease is not fully understood then treatment becomes empirical and to a certain extent unreliable and uncertain. Davis posed six questions about Ludwig's Angina saying we should know:

"1. What is the germ or germs that started the infection;  
2. How do they gain access to the tissues;  
3. What tissues are attacked;  
4. How the infection progresses;  
5. How it influences the parts locally and, finally,  
6. How it affects the system generally".

Davis' report showed that several organisms including Streptococcus, Staphylococcus, Pneumococcus and a mixture of organisms including a gas-producing bacillus could all be the cause of Ludwig's Angina. The common mode of access to the tissues was via infected teeth, though tonsillar infection was also incriminated. The particular tissues attacked and the spread of infection were determined by the location at which the infection commenced. Whenever the teeth were the starting point of the infection the periosteum was always involved but, no matter where the infection commenced, it spread by direct continuity along the connective tissues passing from one side of the jaw to the other side and downward in the neck as far as the clavicles and sternum. It usually involved the larynx and tissues around the oesophagus causing a difficulty in swallowing and breathing. The progress of the severe infections could produce a septic pneumonia, and death would
occur either due to septic infection or due to asphyxiation by laryngeal oedema.

Perhaps, most importantly, Davis noted that many practitioners had never seen or recognised "a bad case of Ludwig's Angina" and that often energetic treatment was deferred until too late. This is still true in 1990, when the disease goes unrecognised in its early stages so that correct surgical management is often not instituted. Davis' conviction that extension of the disease could be cut short by "fearless surgical treatment" is as true today as it was then. Davis stated that "He who waits for the formation of pus before incising waits too long" and advocated that an incision for drainage should be made in the midline between the symphysis and hyoid bone, with expansion of the tissues and placement of drainage tubes. Where oedema of the epiglottis and larynx occurred Davis then advised that tracheostomy should not be deferred too long.

1.7 Thomas 1908

By the time Thomas presented his study on Ludwig's Angina in the Annals of Surgery in 1908, investigations were following two main channels: firstly, bacteriological, attempting to prove that a particular type of infection caused Ludwig's Angina and that septic intoxication therefore was responsible for the systemic involvement and ultimate death; and secondly, anatomical, which tried to show that the condition was due to the particular location of the infection and its opportunities for extension in the tissues of the head and neck.

Bacteriological investigations established that a Streptococcus was present in the majority of infections, either alone or mixed with other organisms, so the conclusion was drawn that Ludwig's Angina was not caused by a specific bacteria but was due to a severe type of ordinary infection. However, it was realised that infection by this bacteria in other parts of
the body did not give rise to such local and constitutional symptoms, nor was it associated with such a high mortality. Therefore, the gravity of the constitutional symptoms must have a definite relationship with the invasion of the tissues of the mouth and pharynx. In Thomas' opinion dyspnoea always occurred and at autopsy oedema of the glottis was always found. He concluded that it was the invasion of the larynx and lungs which was the particularly dangerous feature of Ludwig's Angina and that this was sufficient to be the main cause of the high mortality.

Thomas was able to demonstrate how the process could spread directly along the planes of the connective tissue of the mouth and pharynx, and that regardless of the kind of micro-organisms producing it, an infective swelling in the floor of the mouth could menace the life of the patient. Thomas described the mouth as a box with one side removed, which is filled by the tongue and normal sublingual tissue. When the cellular tissue under the tongue is invaded by inflammatory swelling, the tongue is pushed upward and backward. As the base of the tongue merges laterally with the pharyngeal wall, further spread of inflammation can result in the tongue and epiglottis being pushed against the posterior wall of the pharynx. The intense submaxillary swelling must also be taken into consideration. This prevents downward movement of the mandible so that no relief is found in that direction. Laterally and anteriorly, resistance is provided by bone and teeth and, therefore, the direction of least resistance is backward. Thomas' observations of 104 patients reported a 40% mortality. He was convinced that Ludwig's Angina killed in the majority of patients by invasion of the respiratory tract, first of the larynx and later in some cases of the lungs. Later, this theory was supported by Coakley (1920) who had also noted the sudden increase in laryngeal oedema which could occur in patients with Ludwig's Angina, and that the inhalation of infected material led to septic
pneumonia. He therefore advocated early and adequate surgical intervention.

1.8 Mosher 1920

Harris P. Mosher of Boston recognised that one of the vital structures in the neck from the standpoint of infection was the internal jugular vein lying within the pharyngomaxillary fossa. Both phlebitis and thrombosis of the vein required surgical exposure and investigation urgently, as further spread of infection into the mediastinum, pleura or trachea would produce a fatal outcome. The patient's presentation usually involved difficulty in swallowing and breathing and some hoarseness of the voice; this would then be followed by brawny, indurated swelling of the neck and an inability to move it. Constitutional changes of chills, high fevers and sweats would indicate either a phlebitis or thrombosis of the vein. Mosher thought that no patient showing these symptoms and signs should die without uncovering the internal jugular vein and determining its condition. He considered that "The head was the chief gateway of infection for the body".

1.9 Glogau 1922 and 1923

Glogau reported on abscesses originating within any part of the upper respiratory tract which could descend along the vascular sheath into the deep structures of the neck and mediastinum. Whatever the origin, all these descending abscesses acted in a similar manner and furthermore, surgical access was achieved via the same incision anterior to the sternocleidomastoid muscle allowing exposure of the vascular sheath and drainage of the retropharyngeal, parapharyngeal and retro-oesophageal spaces. This surgical procedure was also described by Dean (1919). At the lowest end of the wound, in the more severe infections, the mediastinum was exposed and sealed with iodoform gauze if still found healthy, and drained if found to be already diseased. This was putting into effect the procedure of the Viennese School - prophylactic mediastinotomy as described by Marschick (Glogau 1922) - to
block the approach of infection to the mediastinum.

1.10 **1928**

Blassingame considered that infections associated with mandibular teeth and the floor of the mouth could develop into Ludwig's Angina. He reviewed the anatomy relating to the floor of the mouth and carried out a series of experiments in which India Ink was injected under the mucosa in various parts of the mouth and fauces of dogs. The results showed that ink injected both under the mucosa above the mylohyoid muscle and into the peritonsillar space, coursed backward and infiltrated the deep cervical glands lying alongside the carotid sheath. However, the ink injected under the mucosa near the front teeth and that ink which also penetrated the mylohyoid muscle at the time of injection, coursed back to the small lymph glands situated on the superficial surface of the submaxillary gland. These experiments indicated the courses which infections about the mouth might be expected to pursue.

In a review of his patients, Blassingame reported that the bacteria isolated were often similar and that the same type of organism was found whether the infection was located in the pharynx, sublingual tissues or deep structures of the neck. The tissue reactions were also similar demonstrating a marked oedema and rapid spread of the inflammatory process with an unusual collection of effusion in the intercellular spaces. Blassingame supported thorough surgical drainage of the involved area advocating that it should be done early in the disease process. In the presence of an enormous swelling about the neck, a small focus of pus situated deeply behind muscles was not easily found and the discharge of pus might only begin 48 hours after incision.

Muckleston presented an historical review and a clinical study which supported the early surgical management of Ludwig's Angina. He emphasised prophylaxis as an essential part of treatment noting the high proportion of
patients where carious teeth provided the initial infection.

Van Wagenen & Costello thought there was some confusion about a group of neck infections which also had sublingual phlegmon as one of its symptoms. They considered that there should be two groups: primary or classical Ludwig's Angina and a further group under the name of secondary Ludwig's Angina which had been defined in Foster's Encyclopaedic Medical Dictionary as "a diffuse phlegmonous inflammation of the floor of the mouth and the intermuscular and subcutaneous tissue of the submaxillary region which may end in gangrene, abscess, or resolution, and which sometimes prevails in an epidemic". It was on the different sites of cervical infection which could give rise to the dominating symptom - sublingual phlegmon - and on the different paths over which the sublingual tissues became infected, and on the different relationships which the phlegmon bore to the whole mass of infection that reasons existed for dividing these cases into two groups as they proposed.

The authors found that the predisposing conditions and the original sources of infection were the same in the two groups of patients studied, but that the clinical course of the secondary disease was less severe, and the symptoms were naturally less fulminating. There was not general support for this rather arbitrary division into primary and secondary diseases. It was thought that the secondary disease was probably a subacute form of the primary disease.

1.11 1929

Ashhurst thought it was important that Ludwig's Angina should be recognised as a cellulitis and not as lymphadenitis or lymphangitis. Cellulitis was the term in common usage in the English language meaning "inflammation of the tissue", while the French preferred the words phlegmon, phlegmoneux and occasionally cellulite and the Germans used
"Zellgewebsentzündung" translating as "inflammation of the cellular tissues".

Ashhurst himself defined Ludwig’s Angina as "an acute inflammatory process involving the cellular tissues of the floor of the mouth and the submaxillary region of one or both sides of the neck", and that "it is the simultaneous involvement of the submaxillary and the sublingual tissues in a confluent septic cellulitis that warrants the condition being recognised as a distinct clinical entity".

Ashhurst concurred with earlier authors that no time should be lost in instituting surgical drainage and considered tracheostomy necessary not only because of glottic oedema, but because the airway was blocked off by the elevated and swollen tongue. However, he did suggest that incision of the swollen tissues in the neck and in the floor of the mouth, could provide relief of dyspnoea within a few hours without resort to tracheostomy; hence the latter operation was to be considered only in patients already moribund.

Mosher presented a paper on "The Submaxillary Fossa Approach to Deep Pus in the Neck", in which he emphasised the applied anatomy of the upper half of the neck noting the important surgical landmarks. He had a conception of all the layers of the deep cervical sheath being off-shoots from the carotid sheath. He described the parotid, the submaxillary and the pharyngomaxillary fossae as three large compartments in the upper part of the neck which communicated more or less directly with the sheath of the great vessels (Figure 2). He liked to call the sheath the "Lincoln Highway of the neck". By following it, one could reach the base of the skull above and the chest below and thus it formed a "natural highway" for pus deep in the neck, and for the surgeon in pursuit of pus. He had no patience with small incisions in the neck especially in life and death surgery and advocated a generous T-shaped incision to provide a broad open field (Figure 3).
FIGURE 2. Relationship of three neck compartments
(Mosher 1929)

FIGURE 3. Mosher's T-shaped neck incision
1.12 1930s

Shapiro (1930) noted that deep cervical infections following tonsillectomy were not rare and appeared to be exclusively a complication of performing the surgery under local anaesthesia. Two clinical varieties were noted:

- a phlegmonous type which formed in the large majority of the patients and could spread to become a Ludwig’s Angina and
- a vascular infection which manifested itself in the form of septicaemia, thrombosis or embolism and offered a bad prognosis.

Houser (1932) in his review of Ludwig’s Angina suggested that more attention should be given to the relief of this condition by intra-oral operation early in its onset before much cervical involvement had occurred. Reasoning for relatively few attempts being made to evacuate such abscesses by oral routes was explained by patients being treated by the general surgeons, who rarely operated within the oral cavity. Such intra-oral drainage could bring about a speedy termination of the infection but if it failed, no harm had been done, and the external operation could still be performed.

August Beck of New York (1933 and 1934) looked at the diagnosis and management of neck infections noting that in spite of the fact that attention had been called to this subject many years ago, the mortality rate was still high. From an analysis of his patients, it was his considered opinion that local signs and symptoms could be explained by the applied anatomy and, where understood and recognised, could indicate the site of the infection and its surgical remedy.

The relationship of the spread of infection to the fascial planes in the head and neck and adjacent regions received considerable attention in the 1930s not only from Beck and Mosher but also by other authors, including
Collier and Yglesias (1935 and 1937), Iglauer (1935), Barlow (1936), Collier and Valk (1939), Grodinsky and Holyoke (1938), Pearse (1938), Lore (1939), Hall (1939), Dingman (1939), New and Erich (1939) and Barnhill (1938). Later, in the 1940s, further descriptions of the connective tissues of the neck and fascial spaces were provided by: Weintraub (1941), Iglauer (1941), Tschissny (1945), Beck (1947) and Shapiro, Sleeper and Guralnick (1949). The anatomy of the cervical fascia and the spread and management of dental infections will be presented in separate chapters.

Based on a study of 24 patients, Beck (1933 and 1934) found that the most common cause of neck infections was inflammation in or about the tonsils and pharynx (58%) followed by odontogenic infections (12%), particularly in the mandible, and then by other less common causes (30%). Beck showed that 50% of these infections were caused by the haemolytic Streptococcus and emphasised the applied anatomy based entirely on the work of Mosher (1929) noting that in severe infections involvement of more than one particular fascial compartment could occur at the same time. Of particular interest was involvement of the pharyngomaxillary space in more than half the patients even in those where the origin of the infection was distant from the space. Beck reiterated that thrombosis of the internal jugular vein was the cause of sepsis which could go unrecognised and result in the patient's death.

Ramsdell (1934) from New York City agreed with previous authors that the clinical diagnosis of Ludwig's Angina was made by noting the location of the two characteristic swellings in the sublingual and submaxillary spaces. He considered that free and adequate drainage could best be accomplished by the complete removal of the submandibular gland, and advocated performing the procedure under local anaesthetic. This was supported by Colp (1933 and 1939) who considered infections of the cellular tissues deep to the submaxillary glands to be incorrectly called Ludwig's
Angina, but realised that they did present a grave surgical problem in which
ergetic and radical treatment was essential. He considered that the
patients were suffering not only from a profound toxaemia but also from the
mechanical effects of an oedematous submaxillary salivary gland pressing
against the lateral pharyngeal wall and indirectly against the larynx
therefore adequate drainage could only be affected by the extirpation of the
submaxillary gland.

Coller and Yglesias (1935) stated that most infections of the lip and
face healed spontaneously but had the potential to spread by a combination
of three routes:

- anatomical continuity
- the vascular system
- the lymphatic system.

They felt, therefore, that proper diagnosis and treatment of facial
infections required an exact anatomical knowledge. They presented in detail
the anatomy of the two types of fascial planes, those associated with muscles
and those associated with viscera and vessels, before discussing the surgical
management of acute parotitis, infections of the upper and lower lips and
Ludwig’s Angina. Particular attention was paid to the severe infections of
the upper lip and nose, which probably originated from ill-advised treatment
of a mild infection, and could result in bacteraemia, meningitis or sinus
thrombosis due to progressive thrombophlebitis of the facial, angular and
superior ophthalmic veins.

Havens (1935) considered only the deeper types of neck infections and
divided them into five classifications:

- acute suppurative conditions in the neck secondary to infections elsewhere
e.g. in the mouth
- woody or ligneous phlegmon, secondary to infection elsewhere with marked
induration and absent suppuration

- infections due to specific causes such as tuberculosis, syphilis, actinomycosis, blastomycosis and tularaemia

- infected cysts and infected tumours

- thyroiditis

Havens (1935) studied a group of 125 patients with neck infections, half of which originated from oral infections. Haven's study emphasised the predominant part that infections of the mouth played as a cause of suppurative processes in the neck. This was in marked contrast to the findings of Beck (1933 and 1934). Havens was at variance with other laryngologists in the management of these patients. He followed a conservative plan of treatment allowing these abscesses to progress to fluctuation or localisation.

Alden (1936) reported his experiences with 29 patients with infection in the fascial planes of the neck, all secondary to dental disease. Although the infections showed mixed bacteria, the most predominant organism was Spirochaeta vincenti which could be controlled by the intravenous administration of neo-arsphenamine. This stopped the rapid spread of a diffuse cellulitis of the neck and localisation would often begin within 24 hours.

Barlow (1936) wished to determine to what extent the general neck structures might be reasonably relied upon to limit, conceal or influence the course of injected fluid. These investigations were made in three ways:

(i) Dissections
(ii) Large serial sections
(iii) Injection experiments

He concluded that the cervical connective tissue was important in directing and spreading injected fluid and that the various fascial spaces
could be demonstrated.

Boemer (1937) reviewed 75 patients which included 26 adults and 49 children who had a history of deep pus in the neck. "Burrowing" of the abscess to the surface and adequate, timely drainage aided by local and supportive measures accounted for recovery in 73 of the patients. It was noted that involvement of the lower third molar tooth accounted for the condition in a third of adult patients, while suppuration of the retropharyngeal glands or of the deep cervical glands accounted for the disease process in all of the 49 children. It was realised that involvement of the parapharyngeal space and the major vessels of the neck constituted the greatest hazard to life.

Grodinsky and Holyoke (1938) gave a very detailed description of the fascia and fascial spaces of the head and neck based on their study of 75 adult cadavers and 5 full-term foetuses by dissection, injection and section methods. This was again reviewed in Grodinsky’s (1939) article on Ludwig’s Angina. Grodinsky found considerable variation in the acuteness and virulence of the disease process in his patients, some fulminating and rapidly fatal and others relatively benign. He considered that the cause of the infection was usually carious teeth and that the mainstay of treatment in Ludwig’s Angina was early and adequate drainage.

Grodinsky (1939) also presented an anatomical and clinical study of "Retropharyngeal and Lateral Pharyngeal Abscesses". Chronic retropharyngeal abscess, usually seen in adults, was most commonly due to tuberculous caries of the cervical vertebrae, while acute retropharyngeal abscess, seen in children, was associated with nasal, throat or middle ear infections. Lateral pharyngeal abscess could be secondary to a retropharyngeal abscess, or abscess in the parotid, masticator or submandibular (Ludwig’s Angina) spaces, or it could be primarily due to extension by continuity via the
lymphatics or veins from the tonsil, lateral wall of pharynx, nose or middle ear. Again the mainstay of treatment was surgical.

White and Hubert (1939) reported on "Parapharyngeal Haemorrhage", when infection has been of such severity as to cause erosion of a large vessel in the parapharyngeal space. This would cause a gradual increase in the size of the swelling of the neck and could cause a mass to form in the lateral wall of the pharynx which would simulate a peritonsillar abscess. When this is incised there may be a small amount of haematoma escape or there may be severe or fatal haemorrhage.

Hall (1939) presented a detailed anatomic and clinical study of "The Parapharyngeal Space". He considered there were 3 types of parapharyngeal infections:

(i) following tonsillar surgery under local anaesthesia
(ii) an extension from a neighbouring compartment
(iii) in which the parapharyngeal space is the seat of the initial invasion of the deep fascia.

Hall recognised four cardinal signs of involvement of the anterior parapharyngeal compartment:

(i) inability to open the mouth widely
(ii) induration about the angle of the jaw
(iii) fever which may be septic in character
(iv) medial bulging of the pharyngeal wall.

He supported early surgical treatment to avoid long convalescences and a high mortality rate.

New and Erich (1938 and 1939) provided a collective review on "Deep Infections of the Neck" and analysed the histories of 267 patients who were treated at the Mayo Clinic for deep cervical infections. They found that numerous factors could lead to the development of a cervical abscess or
cellulitis but "the main cause was the invasion of tissue by pathogenic bacteria". They surmised that the intensity of the inflammatory reaction was proportional to their virulence, and to the resistance of the involved tissues. The vitality of the tissues and their ability to withstand infection were often diminished in patients with chronic diseases such as syphilis, nephritis, or diabetes. The sex and age of patients were shown to be of little or no importance.

Of the 267 patients in New and Erich's (1938 and 1939) study, 101 patients probably had a low-grade infection present somewhere in the ear, nose, throat or mouth which did not give rise to symptoms and remained clinically undetected. Of the remaining 166 patients, 24 patients had infections secondary to tonsillitis and 110 were the result of odontogenic infections. The remaining 32 were miscellaneous cervical infections. They noted that as the oral cavity and pharynx frequently served as the foci of primary infection, the regions of the neck most commonly involved were the submental, submaxillary and upper cervical regions. In summarising their bacteriological studies, New and Erich found that many organisms produced a cervical abscess or cellulitis but the most frequently encountered organism was the *haemolytic Streptococcus*. The authors felt that Ludwig's Angina, which ran a much more rapid course, should be distinguished from other neck infections. As had been noted by Dorrance (1937), in less than 8 to 10 hours a comparatively minor swelling of the neck could become a serious surgical problem with a grave outlook. In their review of treatment of deep infections of the neck, New and Erich recognised two schools of thought. One group of surgeons advocated radical surgical procedures early in the course of these infections so that adequate drainage prevented spread into other fascial spaces. The second group favoured more conservative methods of management with delay of drainage until fluctuation could be detected or
until the process was well localised. The authors considered that internal jugular thrombosis and mediastinitis were very rare complications.

Dingman (1939) reviewed the management of acute infections of the face and jaw and stated that, as many of the acute infections were incidental to dental disease, the oral surgeon should be consulted first. He considered that dental disease was the most prominent aetiological factor, often resulting from the injudicious management of the acutely abscessed tooth and that it was inadvisable to extract such a tooth because of the possibility of spreading infection. In his opinion, localization of the infection by the application of moist heat intra-orally or externally should be undertaken before drainage of the affected area. Once the acute phase of the infection subsided it was safe to extract the tooth.

Beck (1939) presented a paper based on a clinical study of 78 patients with deep neck infections in which he discussed the aetiology, symptomatology, diagnosis and management. The age range in his study was from 8 months old to 81 years old and was evenly distributed between the sexes. Beck considered the aetiology from two standpoints; the bacteria involved in the infection, and the portal of entrance into the tissues. From the bacteriological evidence Beck found that overall, some form of Streptococcus was present in 80% of the patients. This prevalence of the Streptococcus coincided with Thomas' findings in submaxillary infections nearly 30 years earlier. It should be noted that no anaerobic cultures were undertaken. Beck thought that a knowledge of the portal of entrance into the tissues enabled one to anticipate and recognise the pathway of extension into the neck and to determine the site for drainage. The majority of deep neck infections (67% in this study) resulted from infections in the pharynx and the tonsils, and therefore, the most frequent place of cervical involvement was the pharyngomaxillary fossa. When the infection was of dental origin
then invasion of the submaxillary space could be anticipated. A careful history was also important because in some instances the signs and symptoms of the portal of entrance of the infection had disappeared by the time the patient presented with the neck infection. Unchecked neck infections could progress to fatal termination by septicaemia, asphyxiation or haemorrhage. Beck then described the great variability in the manifestations of the symptomatology of neck infection and in the management from that common to all types of infection to that specific for each region.

1.13 1940s

Trout (1940) in his review of Ludwig's Angina recognised the use and limitations of the new drug, sulphanilimide. As it was known to be effective against Streptococci, its use was advocated when dental extractions were carried out in the presence of infection. Trout felt that surgical intervention should not be delayed to await a favourable outcome of the drug and that the administration of sulphanilimide would aid in the postoperative recovery.

Williams (1940) reviewed 31 patients with Ludwig's Angina in the Boston Hospitals and reported a mortality rate of 54%. This rate was nearly as high as that reported by Ludwig a hundred years earlier, which suggested that knowledge of the advances made since that time were not well known, and that the disease still did not receive proper recognition and treatment. Williams placed emphasis not only on the correct surgical approach, but particularly on the establishment of an airway and accorded importance to the role of tracheostomy and the choice of anaesthesia. Having reviewed the aetiology, clinical features and diagnosis of Ludwig's Angina, Williams then discussed the most imminent, most rapid and most insidious of the complications, which was respiratory obstruction. This could be due to blockage of the airway by an elevated or oedematous tongue, or occur in the larynx precipitated by
laryngeal oedema. The most dependable means of securing an adequate airway was to perform a tracheostomy. More important was the ability to recognise impending obstruction, which was heralded by an elevation of the pitch and timbre of the voice described as "crowing", and an increase in the rate, and decrease in the depth of respirations together with the use of the voluntary muscles of respiration. These were all the indications for tracheostomy and the surgeon should not wait for the patient to complain of difficulty in breathing. Williams noted that most surgeons advocated the use of local anaesthesia, which was found to be sufficient for the superficial part of the operation but inadequate for probing the deeper structures. He also felt that injection of a local anaesthetic into infected tissues could foster the progress of infection. However, the alternative of using general anaesthetic agents such as nitrous oxide and ether had the disadvantage of being associated with a high incidence of spastic respiratory obstruction. Endotracheal intubation was considered preferable but was often difficult and sometimes impossible because of the distortion of the airway. The intermittent use of the intravenous anaesthetic agent, pentothal, was tried but caused depression of the respiratory centres leading to cessation of breathing. This article by Williams in 1940 was a succinct resume of the knowledge and management of Ludwig's Angina at that time.

Between 1940 and 1945 a number of articles appeared in the literature presenting reviews of patients with Ludwig's Angina and Deep Neck Infections and emphasising the importance of the surgical anatomy, aetiology and pathogenesis, clinical presentation, diagnosis and treatment. These included Grodinsky (1940), Doherty (1941), Hall (1941), Hall and Morris (1941), Iglauer (1941), Weintraub (1941), Orton (1942), Beck (1942), Taftel and Harvey (1942), McCaskey (1942), Tschiassny (1943 and 1945), Williams and Guralnick (1943).
Taffel and Harvey (1942) wished to dispel the myth that Ludwig's Angina was a sinister affliction and emphasised that when the disease was recognised early and treated promptly the mortality rate would drop. They supported this statement by presenting an analysis of 45 patients treated at the New Haven Hospital, of which only 2 died. They considered that the infectious process whether associated with suppuration or oedema alone, would increase the tension within the submandibular space and displace the floor of the mouth, the tongue and the pharynx and was therefore responsible for the respiratory difficulty. As total respiratory obstruction could occur rapidly, Taffel and Harvey thought that the primary object of the operation was not merely to drain pus, but also to relieve and prevent obstruction by releasing the tension and decompressing the submandibular space.

Tschiassny (1943) questioned the relationship of the mandibular molar teeth to the mylohyoid ridge based on two considerations:

1. Ludwig's Angina started regularly from a focus below the mylohyoid ridge.

2. The mylohyoid muscle was attached to the mandible at the mylohyoid ridge.

He carried out anatomical studies on 23 mandibles and showed that the roots of the second and third molar teeth reached below or at least as far as the level of the mylohyoid ridge. The majority of the apices of the first molar teeth and the root tips of the anterior teeth were above the mylohyoid ridge (Figure 4). Therefore these findings showed that the second and third molar teeth could be the source of submaxillary cellulitis, while the first molar teeth were more likely to be the source of an infection in the sublingual space.

Williams and Guralnick (1943) presented an analysis of 20 patients with Ludwig's Angina seen at the Boston City Hospital. The mortality in this new
FIGURE 4. Lingual surface of mandible showing muscle attachments.

The relationship of the mylohyoid muscle attachment to the apices of the teeth is an important factor in determining whether a sublingual or submandibular abscess will form.
series was 10% compared to 54% in William's first series, and they felt this improvement supported the principles of treatment as advocated by Williams in 1940, which were to establish an airway, to relieve tension, to secure drainage and to combat the infection by supplementary measures. In this series, odontogenic infections were the initiating factor in 90% of patients as compared to 51% in the first series. In over half the group, dental extractions immediately preceded the onset of symptoms, while the rest of the group experienced symptoms but had received no dental treatment. It was concluded that the act of extraction was not so important as was the pre-existing septic tooth or mouth from which the subsequent infection arose. It was, therefore, suggested that many serious post-extraction infections might be avoided by careful pre-operative preparation of the mouth. The authors believed that establishing an airway either by intubation or by tracheostomy was of paramount importance and that immediate surgical drainage was essential in all patients with Ludwig's Angina. They had been unable to control the disease in any patient with the use of sulphanilimide alone. Williams and Guralnick concluded that with their regimen of treatment, the complications of Ludwig's Angina had been substantially reduced.

The mid 1940s heralded the introduction of penicillin and many authors reported on its use in the management of major orofacial infections. They included Herrell and Nichols (1944), Dorner and Morgan (1945), Bean and MacKenzie (1945), Farr and Stanhope (1945), Kimbrig (1945), Kostrubala (1945), Bulteau (1946), Beck (1947), Dutton (1947), Miller (1947), Selsey (1947), Stern (1947), Tschiassny (1947), McGrath (1948), Player (1949).

Beck (1947) again discussed "Deep Neck Infection", and noted that bacteriology had acquired more significance since the advent of antimicrobial chemotherapy. In particular, the reduction in the incidence of pharyngomaxillary space infection was attributed to therapy with
sulphanilamide and penicillin. Beck postulated that infections originating in the dental region may be expected to show a relative increase due to a relative decrease in the number of tonsillar and pharyngeal infections. He also suggested that improved preparation of the mouth prior to the removal of teeth, together with pre-operative administration of penicillin could result in fewer post-operative infections. Penicillin was also of great significance in the management of blood stream involvement making signs and symptoms of sepsis much less evident. Beck concluded that antibiotics would not supplant surgical drainage when the indications for surgery were present, but that the long range benefits of prompt and intensive antibiotic therapy were incalculable.

Herrell (1944) reported on "Penicillin in the treatment of cellulitis of the mouth". Penicillin was found to be highly effective against the majority of the organisms isolated in these patients but at this time its use was restricted to those patients who were desperately ill. They responded quite dramatically to penicillin therapy and therefore it appeared an exceedingly effective means of managing orofacial infection. It is interesting to note that the authors had found no serious side effects with the administration of penicillin.

Seley (1947) emphasised the point that antimicrobial chemotherapy was of greatest value before the formation of pus. Once formed, evacuation of pus is necessary for cure. But, importantly, no therapeutic measure would ever replace tracheostomy for management of the patient with serious mechanical respiratory obstruction.

1.14 1950s

Hall (1950) emphasised that the fascial spaces of the neck were clinical as well as anatomical spaces. As infections had invaded them so frequently these potential anatomical spaces had become clinical entities producing
characteristic signs and symptoms. Therefore, it was disease rather than regional anatomy which had given these areas their clinical importance.

Hall chose three suprahypoid neck infections to discuss:

- pharyngomaxillary
- masticator
- Ludwig's Angina

He described the anatomical features, the characteristic presentation and the management of each infection. He emphasised the following points for:

**Infections of the pharyngomaxillary space:**

"- pharyngeal history
- pharyngeal wall displacement without acute pharyngeal inflammation
- rapidly increasing and severe clinical picture
- only moderate trismus
- easy depression of the tongue on both sides posteriorly
- no fluctuation
- finding of pus medial to the jaw and to the internal pterygoid muscle"

**Infections of the masticator space:**

"- dental history
- extreme trismus
- the posterior portion of the tongue on the affected side was impossible to depress
- no fluctuation
- the patient was not acutely ill as compared to the pharyngomaxillary abscess
- the abscess was on the bone"

**Ludwig's Angina:**

"- the patient is acutely ill with an intense, board-like swelling in the entire submaxillary region"
- an extremely swollen tongue pushed upward against the palate
- dysphagia, dyspnoea, dysphonia and drooling"

Hall agreed that early recognition of Ludwig’s Angina was imperative as surgery provided decompression and drainage. Importantly, in the management of all deep neck infection antibiotics should be used from the onset, but surgical drainage must not be delayed and most importantly, an adequate airway was essential so that a general anaesthetic could be administered.

Schaefer (1950) realised that there was no problem of greater importance to the dentist than the acute infections associated with the teeth. Dentists should be fully aware of the whole physiological picture of the infectious process:

"1. he must be able to recognise the type of pain which has diagnostic significance
2. he must understand the biological process of acute and chronic inflammation
3. he must be familiar with the field of immunology and, more recently, the effects of antibiotics and chemotherapy".

For the dentist, pain can be an important diagnostic aid. A gangrenous pulp in a tooth can produce severe pain which requires the pulp to be opened and drained. Schaefer concluded that antibiotics were suitable for:

1. preventing the beginning of an infectious process
2. aborting it
3. controlling its extension, but if the infectious process had reached the point of localisation then antibiotics would not stop its course.

Eisenbud and Klatell (1951) reviewed 300 patients with acute dentoalveolar abscesses which required hospitalisation. The authors' clinical data was analysed in an effort to determine to what extent
fundamental surgical principles needed to be modified through the advent of antibiotics. Acute dentoalveolar abscesses severe enough to require hospitalisation arose with much greater frequency from the mandibular than from the maxillary permanent teeth. 140 patients were treated prior to antibiotic therapy and 80% required incision and drainage of their abscesses. This contrasts with 151 patients in which antibiotics were used, of which only 48% required drainage. The authors therefore concluded that the use of antibiotics in the management of acute dentoalveolar abscess resulted in a marked reduction in the number of patients requiring drainage of their abscesses for resolution. They also suggested that incision for drainage could be delayed if certain responses to antibiotic therapy occurred. These were enumerated as follows:

"1. The temperature had responded favourably
2. The patient was alert and not toxic
3. There was no respiratory embarrassment
4. There was no threat of spontaneous extra-oral rupture
5. There was no obvious danger of extension into the pharynx or venous sinuses".

Krogh (1951) addressed the age-old controversial question of whether or not teeth should be extracted in the presence of acute infection. He determined that the concensus of opinion in the literature still seemed to be that immediate extraction in the presence of acute infection was not advisable, however, many of the writers had admitted that complications could also occur if extraction was postponed. After analysis of more than 3000 consecutive patients for whom immediate extractions were performed regardless of infection, Krogh disputed the general belief that teeth should not be removed in the presence of acute infection. The use of proper surgical techniques, together with antibiotics, produced no more
complications and generally less severe ones, than extraction delayed until after treatment of the infectious process. In this series there was a total of 78 complications, most of which were minor. Krogh was convinced of the general surgical principle that the best treatment for acute infection was the removal of the nidus of the infection, followed by treatment of the involved contiguous areas if necessary.

Beck (1952), in an interesting paper which straddled two eras, looked at the influence of antibiotic drugs on the incidence and course of deep neck infections, and noted that antibiotics had remarkably influenced the incidence and course of bacterial infections in all parts of the body. He compared two groups of patients, the first group of 78 patients managed in 1939 before antibiotic therapy and the second group of 55 patients observed since 1940, at a time antibiotics were available. In the first group, 56 patients (71%) had infections arising from the pharynx, tonsils and adenoids, while in the second group only 18 patients (32%) had infections arising from these tissues. There was also a striking change in the relative and total incidence of infection in the dental group. In the first group, 16 patients (20%) had infections of odontogenic origin compared with 19 patients (34%) in the second group. There was also a significant increase in the salivary glands as a portal of entrance for infection in the second group. Beck stated that if the patient was seen while the infection was still mostly confined to the portal of entrance, and treated promptly with antibiotics, there was usually good resolution of the infection. It was impossible to estimate how many of these infections would have extended to the neck if they had received no antibiotics but it could be reasonably assumed that the number would have been larger. Since there had been these significant changes in the incidence of infection in the portals of entrance, it may be appreciated that there would also be changes in the regions of involvement
of spread of the infections (noting that each patient may have more than one region involved) (see Table 1).

**TABLE 1: THE REGIONS OF INVOLVEMENT OF SPREAD OF OROFACIAL INFECTIONS**

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(pre-antibiotic)</td>
<td>(antibiotic)</td>
</tr>
<tr>
<td>(78 patients)</td>
<td></td>
<td>(55 patients)</td>
</tr>
<tr>
<td>Pharyngomaxillary (Parapharyngeal)</td>
<td>53%</td>
<td>29%</td>
</tr>
<tr>
<td>Submaxillary (Ludwig's Angina)</td>
<td>23%</td>
<td>58%</td>
</tr>
<tr>
<td>Visceral (Buccopharyngeal + pretracheal)</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Carotid sheath + blood stream infection</td>
<td>14%</td>
<td>3%</td>
</tr>
<tr>
<td>Prevertebral Retropharyngeal (Retropharyngeal)</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Lymphadenitis with and without abscesses</td>
<td>56%</td>
<td>43%</td>
</tr>
</tbody>
</table>

The most significant differences were the considerable reduction in number of pharyngomaxillary infections and the predominance of the submaxillary type of infections which was proportional to the relative increase in incidence of odontogenic infections in the second group. Carotid sheath and blood stream infections also showed significant reduction in the second group which was evidence that the antibiotics exerted a pronounced protection against sepsis. The presence of lymphadenitis with or without abscess formation showed that despite antibiotics the lymphatic system is still very actively concerned, in a protective sense, in the presence of infection.
Beck found the information derived from routine bacteriological investigations in these patients quite confusing. In those patients who had recovered without surgery the culture had been taken from the portal of entrance of the bacteria and it was, therefore, a mixture of organisms, any one of which could be the invader of the neck. Sometimes, organisms from an abscess did not grow on cultures even when a large quantity of pus was transferred to the culture medium, and it then appeared that the organisms had been rendered incapable of growth by the antibiotic therapy. Pathogenic organisms could also be cultured from a perfectly normal mouth and throat. Though bacterial sensitivity tests could help by indicating the selection of the most effective antibiotics, surgical drainage often produced recovery before the sensitivity results were available.

Several conclusions were reached by Beck:

"a) there is not the predominance of the *Streptococcus haemolyticus* in the antibiotic group that there is in the pre-antibiotic group;
b) the antibiotics do exert a definite inhibitory effect on the growth of organisms on culture;
c) the antibiotics, particularly penicillin, have had their best effect on the *Streptococcus haemolyticus*; and
d) the other organisms now encountered, such as the *staphylococci*, are more resistant".

Also, Beck found that the complication rate had not changed, but of significance was the change in kind and degree. He also discussed the diagnostic dilemmas that could arise following administration of antibiotics which changed the clinical presentation. Formerly, the local and general manifestations of orofacial infections were frank and severe, but following antibiotic therapy these were significantly reduced so that the patient did not seem so ill. Surrounding tissue inflammation and oedema, together with
the incidence of abscess formation, were decreased so that less extensive operations were required. Beck's opinion was that surgical drainage was indicated if the disease did not respond to antibiotic therapy within two to four days. However, if there were any doubts, then drainage was still the safest course. "It was still not yet time to throw away the scalpels."

Numerous other articles in the 1950s on both the anatomical spread of odontogenic infections and the clinical management of patients with Ludwig's Angina appeared in the literature and included Shapiro (1950), Sleeper and Guralnick (1950), Casberg (1950), Burman (1951), Archer (1952), Kalman and Nathanson (1953), Sherman, Breakstone and Feingold (1953), Herd and Hall (1954), Mohiuddin and Martin (1954), Beck (1955), Snitman and Soboroff (1956), Gaughran (1957), Kelly, Hodge and Grossman (1957).

1.15 **1960s**

In the 1960s debate continued on the relative merits of surgical and medical therapy of orofacial infections, particularly Ludwig's Angina. The pathways of spread of infection in the face and neck were reviewed, and the general management of such infections both locally and systemically were discussed. The authors included Waite (1960), Kleinman (1961), Danforth (1963), Kay & Killey (1963), Hora (1963), Johnson, Devine, Wellman and Fischbach (1963), Laskin (1964), Waite & Bradley (1965), Gutman Laufer & Neder (1965); Williams & Davis (1965), Spilka (1966), Wright (1967), Hall, Gunter, Jamison & McCallum (1968) and Crystal, Day, Wagner & Kranz (1969).

Waite (1960) realised that the development of the antibiotic era had not been particularly helpful from the diagnostic standpoint as many orofacial infections received a standard broad-spectrum antibiotic treatment without regard for diagnosis or aetiology. He reiterated the necessity for the clinician to have a thorough knowledge of the anatomy of the tissues involved and proposed the following outline as a guide for the successful
treatment of acute orofacial infections:

"1. The bacteria are combated with chemotherapy

2. The tissues are treated by:
   a. incision and drainage
   b. removal of diseased teeth and necrotic bone

3. Supportive therapy:
   a. rest
   b. fluids
   c. nourishment
   d. analgesics
   e. physical therapy".

In addition, Waite emphasised the importance of bacterial culture and sensitivity tests so that a careful choice of antibiotics could be made.

Waite and Bradley (1965) emphasised the importance of the care of the tissues of the oral cavity and the seriousness of the problems involved when oral hygiene was neglected. For patients with orofacial infections the upgrading of oral hygiene and the selective removal of involved teeth are most important aspects of management.

Hora (1963) thought that deep neck infections were subtle in their presentation. The surgeon was faced with three decisions:

"1. Which space is involved?

2. What is the causative organism?

3. Is surgical or medical therapy indicated?, If surgical - what approach will best accomplish drainage of the area?, If medical - what antibiotics are to be used?"

The space involved can be answered by careful history and physical examination while the causative organisms can be identified by culture methods. If pus is present then surgical intervention is indicated. Hora
stated that antibiotics are never a substitute for surgical drainage.

Johnson et al (1963) supported essentially conservative treatment following control of the airway by the establishment of a tracheostomy. They felt there was no rationale for surgical incision for so-called "surgical decompression" unless suppuration was present and managed the local infection with intensive antibiotic therapy. However, it should be recognised that deep pus can be found in neck infections but may only commence draining 24 to 48 hours after the incision is made.

Gutman et al (1965) reported on the only 2 patients with Ludwig's Angina seen in their department among approximately 250 patients with severe orofacial infections involving the submandibular region. In their discussion of the management of their 2 patients they felt that the severity of the disease was underestimated, which may have caused an unnecessary delay in performing a tracheostomy. Their aim in performing tracheostomy was not only for management of impending airway obstruction but also to prevent cardiopulmonary complications. They, like Johnson et al, doubted the value of surgical incision unless fluctuation was present, though they felt that culture of the serum found through the incision did help in establishing bacterial culture and sensitivities. They stressed the value of general supportive therapy and immediate administration of high levels of empirical antibiotics.

Hall et al (1968) looked at the "Effect of time of extraction on resolution of odontogenic cellulitis". 350 patients were included in their trial. It was found that there was greater initial relief from pain in patients in whom infected teeth were extracted on day one than in patients for whom extractions were delayed until day three or four. Patients who had immediate extraction of their infected teeth also showed a greater degree of improvement than did patients who had delayed extractions. The procedure of
incision and drainage was performed in 28% of patients in the delayed extraction group compared with 14% in the immediate extraction group. Furthermore, it was necessary to make an extraoral incision in 42% of the delayed extraction group in contrast to only 27% of the immediate extraction group. The other major difference was in the administration of antibiotics; 70% of the immediate extraction group were treated with an antibiotic whereas 97% of the delayed extraction group were administered antibiotics. The authors felt that the early extraction of infected teeth was a safe procedure and that it aided the resolution of the cellulitis and facial pain and decreased the need for incision and drainage.

Crystal et al (1969) reporting on "Emergency treatment in Ludwig's Angina" pointed out, yet again, the importance of establishing a patent airway stating that there may be nothing elective about the need for tracheostomy. Only slightly less important was the need to accomplish true surgical drainage. Hospital staff should recognise the rapidity of respiratory obstruction with a Ludwig's Angina and not be lulled into a false sense of security arising from the use of antibiotics.

1.16 1970s

In the 1970s it was realised that antibiotics were not a panacea for deep neck infections nor a substitute for surgery, and should only be used in conjunction with proper surgical drainage. Though the overall incidence of these infections over the previous 30 years had decreased, in many respects their diagnosis and management had become more difficult due to the masking of the natural course of the illness by antibiotics. Prior to antibiotics, most deep neck infections were caused by members of the pyogenic group of bacteria, particularly the Streptococcus group, but with the introduction of antibiotics a greater variety of causative organisms were appearing, including gram negative pathogens and resistant strains. Overall,
there had been a decreased incidence of deep neck infections originating from the pharyngeal and tonsillar areas, and an increased incidence of infection attributed to odontogenic and salivary gland problems. This correlated with a reduction in pharyngomaxillary space infections and an increase in the incidence of submaxillary space infections.


1.17 1980s

Hought et al (1980) presented the successful management of 2 patients who developed Ludwig’s Angina and reviewed the 75 patients with Ludwig’s
Angina reported in the English literature between 1945 and January 1979. They found a consensus among authors that Ludwig's Angina was "an aggressive infection that bilaterally involved the submandibular, sublingual and submental fascial spaces". Odontogenic infection was involved in the aetiology of Ludwig's Angina in 70% of patients. They believed that the original impression of Streptococci as the predominant bacteria still held true, but that other organisms or combinations of pathogens could be responsible. They found a significant decline in the mortality rate, 9.3% against the pre-antibiotic incidence of 54%. Treatment revolved around a three way approach:

- airway management
- antibiotics
- surgical drainage

As Streptococci were cultured in 42% of Hought et al's patients, penicillin was the preferred choice. Other antibiotics could be used alone, or in combination pending the results of the culture and sensitivity tests, and the clinical course of the disease. The need for surgical drainage procedures remained controversial since some authors believed that modern chemotherapy rendered the need for drainage infrequent. Fluctuation was often not apparent due to the deep-seated nature of the infection but importantly, frank pus was found on incision and drainage and it was therefore appropriate to consider the need for drainage and not to rely on antibiotic therapy entirely. However, in both the pre-antibiotic and antibiotic era, the airway remained the prime concern of the surgeon in the initial management of this potentially life-threatening disease.

Beck et al (1984) reviewed "Life-threatening Soft Tissue Infections of the Neck" in both compromised and uncompromised patients and felt there was a need for a greater awareness of the potentially aggressive nature of these
infections. These soft tissue infections of the neck could be either necrotising or non-necrotising. Cellulitis secondary to *Haemophilus influenzae* and *beta-haemolytic Streptococci* is usually non-necrotising, whereas necrotising infections are caused more commonly by organisms acting in synergism. The authors considered that non-necrotising infections could be managed with antimicrobial therapy. The presence of *Haemophilus influenzae* should always be considered when there is an associated infection of the respiratory tract. This characteristic cellulitis occurs on the face, usually the buccal and periorbital areas, beginning as a tender, indurated, purplish-red lesion with ill-defined borders which spreads on the face and neck. Confirmation is by blood culture and management is with ampicillin or chloramphenicol or alternatively with a new beta-lactam antibiotic when there is ampicillin-resistance. Streptococcal infections are uniformly sensitive to penicillin, the drug of choice. Necrosis in a soft-tissue infection of the neck requires surgical exploration and debridement (see 8.8), in addition to antimicrobial therapy. The causative organisms usually include Streptococci in combination with anaerobic Bacteroides and Clostridial species. The authors emphasised that it should not be forgotten that cellulitis of the neck can progress rapidly with a potential for the development of systemic toxicity and airway compromise.

Stiernberg (1986) reported on the management of eight patients with deep neck space infections and included the following guidelines for management:

(i) immediate hospitalisation
(ii) aspiration for culture and sensitivity tests
(iii) intravenous antibiotics, commencing empirically with penicillin
(iv) diagnostic radiographic procedures including C.T. scan
(v) incision and drainage when there is evidence of abscess formation or
if the infection fails to improve within forty-eight hours after
initiation of antibiotic therapy

Moreland et al (1988) reported on their patient with Ludwig’s Angina
associated with *Haemophilus influenzae* and reviewed the literature on
Ludwig’s Angina with special emphasis on the antibiotic era. They showed
that in the 141 cases reported since 1945, the mean age of the patients was
29 years (range 12 days to 83 years) and 85% of them were essentially healthy
individuals. Information about possible aetiological factors was available
for 116 of these patients, 85% of which had an odontogenic cause, usually the
mandibular second or third molar tooth. Surgical management included
tracheostomy (42%), incision and drainage (65%), and dental extractions
(20%). Only in 12% of patients was no surgical intervention carried out.
Of course, many patients had a combination of surgical procedures.
Antibiotic therapy was used for nearly all the patients with penicillin being
the most commonly used drug. Cultures were available for 71 patients and the
most commonly reported organisms were Streptococcus, Staphylococcus and
Bacteroides species.

Other reports in the 1980s included Dever, Sazima and Schaberg (1980),
Finch, Snider and Sprinkle (1980), Kaban (1980), Clarke (1981), Schmit and
Johnson (1981), Bates, Taylor, Mainous and Causey (1982), Patterson, Kelly
and Strome (1982), Piecuch (1982), Yeo and Loh (1982), Heimdahl and Nord
and Yonkers (1984), Dzyak and Zide (1984), Hall (1984), Johnson (1984), Quinn
and Guernsey (1985), Rothwell (1985), Young, Johnson, Lunden, Kuker and
Tom and Rice (1988).

The general consensus was that recognition and aggressive management of
Ludwig’s Angina and Deep Neck Infections, with respect to maintenance of the
airway, antibiotic therapy and early surgical intervention, had resulted in a significant drop in the mortality rate of disease which once led "almost uniformly to a fatal ending".
CHAPTER 2

THE FASCIA AND FASCIAL SPACES OF THE HEAD AND NECK
2.1 Introduction

When considering infections of the head and neck regions, the modern surgeon must have a clear understanding of the anatomic compartments that become involved. Once outside the bones, it is the muscle attachments and the distribution of the connective tissue or fascia which govern the direct spread of infection. In the head and neck, fascia is described as "a localised concentration of the general connective tissue permeating the body". The clinical significance of the cervical fascial planes is dependent on their relation to:

1. their function as directives or limitants in the spread of extravasations, whether these be inflammatory or haemorrhagic
2. their aid as diagnostic and therapeutic landmarks
3. their role in the support of adjacent structures
4. their influence on the direction of expansion of neoplasms
   (Grodinsky and Holyoke 1938).

The fascia of the head and neck has been a subject of controversy since its first description by Burns in 1811, though the first experiments to study the compartments of the neck were undertaken by Bichat in 1801 in France. The pioneer work of Burns gave impetus to further research by various men during the 19th century: Velpeau 1826-1837, Proriep 1834, Malgaigne 1838, Richet 1857, Dittel 1857, Gruber 1868, Juvara 1870, Henke 1872, Tillaux 1882, Poulson 1886, Taguchi 1890 and Merkel 1892. There were numerous discrepancies in their descriptions which were well summed up by Malgaigne's statement that "the cervical fasciae appear in a new form under the pen of each author who attempts to describe them". These earlier descriptions of the cervical fascia divided them into two main layers, superficial and deep (Richet 1857; Poulson 1886).

The surgeons in the early part of the twentieth century appreciated the
importance of the spread of infection in the head and neck and the necessity for opening up the neck to allow drainage, but the deep anatomy of the face remained largely neglected until Coller and Yglesias reported their findings in 1935 and 1937. It was realised that the fascia is important in circumscribing and separating various structures such as muscle groups, blood vessels and nerves and that, clinically, it is important in surgical orientation and in directing the course of infection.

2.2 Mosher 1920 and 1929

Mosher drew attention to the importance of the cervical fascia in limiting and directing the spread of pus. He thought that the purpose of the fascia was to keep everything in the neck snugly in its allotted place and regarded the fascia as prolongations or off-shoots of the carotid sheath. This conception of the carotid sheath and the cervical fascia made the sheath the core of the soft structures of the neck and Mosher, as stated previously, liked to call it the "Lincoln Highway". By following it one could reach the base of the skull above and the chest below, so that in hunting for pus deep in the neck Mosher advocated finding the "Lincoln Highway" and following it.

Mosher briefly described the three fascial layers of the Deep Fascia:

1. The Superficial layer split to enclose the sternomastoid and the trapezius muscles and form a sheath for the submaxillary gland.

2. The Middle Layer which is attached to the hyoid bone, covered the muscles above it forming the floor of the submaxillary triangle. Below it, this layer formed a sheath for the depressors of the hyoid bone. Extensions from the deep surface made a sheath for the trachea, thyroid gland and great vessels of the neck.

3. The Deep or Prevertebral Layer covered the prevertebral muscles and lay behind the oesophagus and the pharynx.

In relation to these layers, Mosher pointed out that 4 fascial
compartments or spaces seemed to exist in which pus might accumulate (Figure 5).

The first space (1) lay between the superficial layer of the deep fascia and the superficial fascia, and contained the platysma and the external jugular vein. From this space pus could reach the surface of the skin with relative ease.

The second space (2) was between the superficial and middle layers of the deep fascia and contained the submaxillary glands above and the infrahyoid muscles and anterior jugular veins below. The two parts did not communicate because of the attachment of the superficial layer to the hyoid bone and pus was prevented from entering the thorax by the attachment of the middle layer to the sternum and clavicles.

The third compartment (3) was described as containing the visceral group of structures (trachea, oesophagus and thyroid gland), the great vessels and the lymph nodes. Because this space was covered by both the superficial and middle layers of fascia, the presence of pus was obscured and had great difficulty in working its way to the surface.

The fourth compartment (4) lay behind the pharynx and oesophagus. Below the level of the hyoid it ran directly into the third compartment, whilst above that level it lay behind and at the side of the pharynx, a position which Mosher called the pharyngomaxillary fossa.

Mosher placed particular emphasis on the importance of the pharyngomaxillary and submaxillary spaces and on the frequency with which jugular vein thrombosis occurred in the many different types of neck suppuration as a consequence of delayed drainage.

Beck (1933) reaffirmed the importance of the above spaces. From the point of view of deep suppuration in the neck, he visualised the upper cervical region as the leaves of a "trifolium" of which the carotid sheath
FIGURE 5. The four fascial spaces made by the cervical fascia (Mosher 1929)
was the stalk. The three "leaves" were the submaxillary, the parotid and the pharyngomaxillary spaces. Beck believed that the four spaces were in more or less direct intercommunication (Figure 6).

Barlow (1936) confirmed this in his research so far as the upper three spaces were concerned, though he made certain reservations with regard to the carotid sheath. There seemed to be no doubt clinically that pus could pass from either the parotid or submaxillary regions into the lateral pharyngeal region, and thus accumulate, very deeply, external to the constrictor muscles and internal to the parotid gland and the internal pterygoid muscle. As a result of such suppuration, thrombosis of the internal jugular vein could occur.

2.3 Coller and Yglesias 1935 and 1937

The relationship of the spread of infection to fascial planes in the face, neck and thorax were well described by Coller and Yglesias in 1935 and 1937 and is presented here in detail.

The spread of infection by anatomical continuity is directed by two types of fascial planes:
- those associated with muscles which are always adjacent to bone at the muscle insertion thereby sharply limiting infections in these spaces;
- those associated with viscera and vessels which allow infection in them to pass readily from one region to another.

In the face there are three muscular fascial spaces:

i. space of the body of the mandible
ii. masticator space
iii. parotid space

and one viscerovascular space:
lateral pharyngeal or pharyngomaxillary space

In the neck there are three muscular fascial spaces and one
FIGURE 6. Fascial compartments in the upper part of the neck
viscerovascular space which has four subcompartments (Figures 7, 8 and 9).

The Face:

The superficial and middle layers of the muscular fascia of the face fuse above the hyoid bone and ascend to the inferior border of the mandible where the fused fascia divides into a superficial and a deep layer. The superficial layer attaches to and reinforces the periosteum of the anterior aspect of the body of the mandible. It also covers the masseter muscle and passes deep to the parotid gland, its duct and the facial nerves and vessels. The deep division of the fused fascia attaches to and reinforces the periosteum of the posterior border of the mandible and continues upward to surround the internal and external pterygoid muscles, forming their fascial coverings. The fascial space between the superficial and deep divisions may be called the space of the body of the mandible. Here, infections may remain localised, may discharge into the mouth or may spread to the masticator space. This space may be drained either intra-orally via an incision in the mucous membrane or by an incision through the skin along the inferior border of the body of the mandible, when the incision must be carried to the bone.

The masticator space is the second muscular fascial space occupying the ramus of the mandible bounded laterally by the masseter muscle, medially by the pterygoid muscles and superiorly by the temporalis muscle. Infection cannot spread downward, medially or superficially without destruction of its walls but it can spread upward either to the superficial or deep temporal spaces or to both.

The superficial temporal space is bounded internally by the temporalis muscle and externally by the fascia. The deep temporal space lies between the temporalis muscle on its deep aspect and the periosteum of the temporal bone and the external pterygoid muscles internally.

The parotid space is occupied by the parotid gland. The superficial
FIGURE 7. Frontal and horizontal sections demonstrating the different fascial planes and potential anatomic spaces (Collier and Yglesias 1935)
FIGURE 8. Sagittal section through neck and thorax showing fascial planes and spaces (Coller and Yglesias 1937)
FIGURE 9. Horizontal section at the neck showing dissection of the fascial planes and spaces (Coller and Yglesias 1937)
part of the gland lies between the subcutaneous tissue and the fascia forming the external wall of the masticator space. The deep portion of the gland is enclosed anteriorly by the posterior border of the ramus of the jaw, superiorly by the external auditory canal and posteriorly by the mastoid. The medial wall of the parotid space is formed by the first and second fascial planes as they extend backward from the posterior border of the mandible and the internal pterygoid muscles. These walls separate the parotid gland from the lateral pharyngeal space and infections may pass through this wall in either direction. Therefore, a peritonsillar abscess may point in the lateral pharyngeal space and may then infect the parotid gland. Infections of the superficial portions of the parotid gland may spread anteriorly along the duct to reach the face, or conversely, infections of the anterior aspect of the face may follow the same path to reach the parotid space.

The only viscerovascular space to be considered in relation to the face is the lateral pharyngeal space also known as the pharyngomaxillary space. It is bounded anteriorly by the medial wall of the masticator space, laterally by the parotid space, posteriorly by the carotid sheath and its contents, and medially by the pharynx and its fascia. Above, it is limited by the base of the skull and below by the submaxillary gland with its fascial sheath. Infection of this space may derive from infections in the lateral wall of the pharynx, such as in tonsillitis or peritonsillar abscess, or the space may become secondarily infected from infections of the retropharyngeal or parotid spaces. Infection from this space can pass unhindered into the carotid sheath and thus gain entry into the vascular visceral spaces of the neck and mediastinum.

The region of the face bounded laterally by the masticator spaces, inferiorly by the mandible and superiorly by the hairline contains the lips,
nose, cheek and the organs of special senses. This region is covered by skin and subcutaneous tissue. The underlying muscles of facial expression do not have a fascial covering and therefore, there are no fascial planes to limit infection, which spreads easily in the subcutaneous tissue. Infections of the lower lip arising on the inner aspect or from the lower incisor teeth or from the floor of the mouth may pass along the lymphatics from this area to well-defined spaces lying above and below the geniohyoid muscles. The superficial space which lies between the genioglossus and geniohyoid muscles is bounded laterally by the body of the mandible and is medially divided by a median fascial septum, while the deeper space which lies between the geniohyoid and mylohyoid muscles is also bounded laterally by the body of the mandible and divided by the same fascial septum. Another potential space lies between the mucous membrane and the genioglossus muscle which contains the sublingual gland. Infections in these areas can give rise to Ludwig’s Angina which, if neglected, will break through the walls of these spaces and may involve the lateral pharyngeal fossa.

The Neck:

The first muscular fascial plane encloses the sternocleidomastoid and trapezius muscles. This fascia is continuous above with the fascia of the masticator space and extends down to blend with the periosteum of the clavicle and sternum.

The second muscular fascial plane encloses the sternohyoid and omohyoid muscles. Above, it joins the first layer of fascia at the hyoid base to form the fused fascia, and below at the superior surface of the sternum, it splits into two layers to form the suprasternal space.

The third muscular fascial plane is composed of the fascia enclosing the sternothyroid and thyrohyoid muscles continuing above to the hyoid bone. The lateral border of this layer fuses with the fascial sheath of the internal
jugular vein while inferiorly it is attached to the posterior border of the manubrium and the first rib.

The viscerovascular system

This highly important fascial compartment extends from the skull to the fibrous portion of the pericardium in a cylindrical shape, enclosing the posterior and lateral walls of the pharynx, the ascending aorta, the arch of the aorta, the subclavian and carotid artery and its branches, the internal jugular vein, the vagus cervical chain, the hypoglossal and spinal accessory nerves and the submaxillary, thyroid and thymus glands, the larynx, the trachea and oesophagus. This space is of the greatest importance to the surgeon since it connects the mouth, throat and pharynx with the mediastinum through the neck and is the route along which infection may commonly pass.

The space of the submaxillary gland

The submaxillary gland is surrounded by the portion of the viscerovascular fascia that surrounds the pharynx and the floor of the mouth, and is separated from the parotid space by the fused fascia. The anterior belly of the digastric muscle and the insertion of the second muscular fascial plane to the hyoid bone act as a barrier below to the spread of infection from the gland. Posteriorly the fascial covering of the gland is connected to the external carotid sheath and forms the floor of the lateral pharyngeal space. In both situations, neglected infections may perforate, and thus infect, the viscerovascular space.

The pretracheal space

The fascia from the submaxillary region is continued downward to surround the larynx and the thyroid gland. The superficial leaf covers the anterior surface of the thyroid gland and the deep leaf connects with the carotid sheath laterally and from here passes down to surround the trachea and oesophagus. Between this previsceral portion and the trachea and
oesophagus is a potential space known as the previsceral or pretracheal space. The space is limited below by the pericardium and above by the superior attachments of the thyroid gland so infections arising from the lateral wall of the pharynx or from the lateral pharyngeal space may extend down to infect this entire pretracheal space.

The retrovisceral space

The fascia that covers the posterior wall of the pharynx and oesophagus is the retrovisceral portion of the viscerovascular system. Between this and the prevertebral fascia is a large and important space bounded laterally in the neck by the fusing of these fascia at that point where they surround the cervical sympathetic chain. It extends up to the base of the skull and down to the diaphragm. This space, called the retrovisceral space, is also known as the retropharyngeal space and the prevertebral space. Infections of this space from the neck will descend with ease to the bifurcation of the trachea but may be stopped here by the obliteration of the space by the approximation of the pleura.

The final space in the neck is that associated with the lymphatic chains. The superficial group lies under the platysma along the external jugular vein and when infected produces only local abscesses. The deeper chain lies in a space along the great vessels and infection here may pass directly to the axilla. The lymph nodes may be involved by infection originating in the face, lips, mouth, tonsils, pharynx or oesophagus.

Coller and Iglesias, having described the fascial spaces in the face and neck, concluded that the lateral pharyngeal space was a "receiving station" for infections arising from fascial spaces in the face and pharynx, from which infection may pass to all other compartments of the viscerovascular system.
2.4 Grodinsky and Holyoke 1939

These authors reviewed the literature on the subject of fascia of the head and neck and gave the following description which was based upon data obtained by dissection of and injections into 75 adult cadavers and by serial sections of one adult cadaver and of five full term foetuses.

This pattern of fascia and fascial spaces of the head and neck has been used by many authors and therefore will be described here (Figures 10, 11, 12 and 13).

**Fascia:**

- **Superficial Fascia**

- **Deep Fascia**
  - superficial layer of deep fascia
  - middle layer of deep fascia
    - sterno-omohyoid layer
    - sternothyroid-thyrohyoid layer
    - visceral layer (pretracheal or buccopharyngeal)
  - deepest layer of deep fascia
    - alar
    - prevertebral

**Fascial Spaces:**

- **Superficial Space of Head and Neck** (space 1)

- **Deep Fascial Spaces**
  - **I Spaces of the Infrahypoid Region**
    - spaces 2, 3, 4 and 5 (these designations and descriptions do not correspond with those of other investigators)
  - **II Spaces of the Suprahypoid Region**
    - submandibular space
    - space of the body of the mandible
FIGURE 10. Diagrammatic drawing of fasciae of head and neck in midsagittal section (Grodinsky 1939)
FIGURE 11. Diagram of fasciae of the head and neck
A. At the level of the sixth cervical vertebra and
B. To show the relationship of the submandibular space
to the lateral pharyngeal space and spaces 3 and 4
FIGURE 12. Diagram of sagittal section showing fascial spaces above the hyoid bone

FIGURE 13. Diagram of oblique section showing the general relationship of the periphraryngeal spaces
- lateral pharyngeal space
- masticator and temporal spaces
- parotid space

The superficial fascia is described as a continuous sheet extending from the head and neck into the regions of the thorax, shoulders and axillae, containing the platysma muscle in its deep layer. The superficial fascia in the face, which contains the muscles of facial expression, is much denser than in the neck except in the region of the eyelids. Similarly, in the scalp the superficial fascia is again very dense containing the epicranius muscle in its deep portion. Deep to the epicranius, between it and the periosteum, lies a loose areolar space permitting the movement of the skull soft tissues and capable of holding large amounts of fluid. Therefore, there is the possibility of transmitting infection between this space and the interior of the skull via the emissary veins.

The superficial layer of the deep fascia is confined to a definite sheet of fibrous tissue completely encircling the neck, extending into the face superiorly and into the pectoral and axillary regions inferiorly and splitting to enclose the sternomastoid and trapezius muscles.

At the level of the hyoid bone the sternohyoid-omohyoid and the sternohyoid-thyrohyoid divisions of the middle cervical fascia fuse with the superficial layer of deep fascia. Thus, superior to this level all three are fused into one layer. It then passes up to split and form the capsule of the submandibular gland. At the angle of the jaw and the anterior border of the sternomastoid muscle the sheath splits to enclose the parotid gland. Contrary to previous reports, Grodinsky and Holyoke considered that the parotid gland has a complete capsule of deep fascia and is related to the masticator space anteriorly and to the lateral pharyngeal space medially.

From the body of the mandible the superficial layer of deep fascia
extends superiorly to form the sheath of the masseter muscle and attaches to the zygoma. This fascia also passes around the ramus of the mandible and becomes continuous with the sheaths of the pterygoid muscles. The space containing the masseter and pterygoid muscles and the ramus of the mandible is called the masticator space.

Overlaying the temporal muscle two main layers of deep fascia are distinguished; a thick outer layer attached to the temporal ridge superiorly and posteriorly, the orbital margin anteriorly and the zygoma inferiorly, and a thinner layer with similar attachments superiorly which closely follows the muscle tendon deep to the zygoma to its insertion. The two temporal spaces are continuous around the anterior border of the temporalis tendon.

The middle layer of the deep fascia is described as having three subdivisions:
- sternohyoid-omohyoid layer forming the sheaths of the muscles indicated
- sternothyroid-thyrohyoid layer forming the sheaths of the muscles indicated
- the visceral layer (pretracheal or buccopharyngeal) which completely surrounds the thyroid gland, trachea and oesophagus. Superiorly, it attaches to the base of the skull on the posterior side, and to the thyroid cartilage and hyoid bone on the anterior and lateral sides. Inferiorly, at the root of the neck, it fuses with the alar fascia of the anterior wall of the carotid sheath and becomes continuous with the fibrous pericardium, and more inferiorly covers the thoracic portion of the trachea and oesophagus.

The posterior or deepest layer of deep fascia consists of two main subdivisions: the alar and the prevertebral.

The alar fascia lies between the visceral and prevertebral layers extending across the midline, posterior to the pharynx, oesophagus and visceral fascia and fusing with the prevertebral fascia at the tips of the
transverse processes, and then passing anterolaterally to form the medial anterior wall of the carotid sheath. From its attachment to the prevertebral layer at the transverse processes, the alar fascia passes around posterior to the carotid artery, jugular vein and vagus nerve to form the posterior and lateral walls of the carotid sheath, and then fuses with the sheath of the sternomastoid and finally connects in the midline. Posteriorly the alar fascia extends from the base of the skull to about the seventh cervical vertebra where it fuses with the visceral fascia anterior to it closing off space 3 inferiorly (see page 69).

The carotid sheath is made up primarily of alar fascia. Within the sheath are separate individual sheaths for each of its main constituents.

The prevertebral fascia lies anterior to the bodies of the vertebrae from the base of the skull to the coccyx. In the neck, it extends laterally to the tips of the transverse processes where it fuses both to these processes and to the alar fascia. Lateral to the transverse processes it continues as the sheaths of the anterior, middle and posterior scaleni muscles thus becoming the scalenus fascia.

Superficial space of head and neck - Space 1

This is the potential space between the skin and superficial layer of deep fascia; i.e. within the superficial fascia and between it and the deep fascia.

Deep Fascial Spaces

I. Spaces of the Infrahyoid Region

These potential spaces have been roughly divided into those of the anterior and posterior triangles, the former being designated by numerals and the latter by the corresponding numerals followed by the letter A.

Space 2 lies between the superficial layer of deep fascia and the deep surface of the sternothyroid fascia.
Space 2A in the posterior triangle lies between the superficial layer of deep fascia and the sheath of the posterior belly of the omohyoid.

Space 3 is a potential areolar space between the visceral fascia surrounding the thyroid gland, trachea and oesophagus and the sternothyroid layer anteriorly, the carotid sheath laterally, and the alar fascia posteriorly. This space extends from the base of the skull to a level varying between the sixth cervical and the fourth thoracic vertebrae and anteriorly from the thyroid cartilage to the upper border of the arch of the aorta. The thyroid gland, trachea and oesophagus are each enclosed within true capsules which have potential spaces surrounding them, as well as between them and the outer capsule of visceral fascia.

Space 3A is the potential space within the carotid sheath. Contrary to other investigators, Grodinsky and Holyoke found a marked tendency for infections within the carotid sheath to remain localised within the cervical region. Infections of this space most likely follow thrombosis of the internal jugular vein or infection of the internal group of deep cervical lymph nodes.

Space 4 is often referred to as the "danger space" because of its relation to the posterior mediastinum. It lies between the alar and prevertebral layers and extends from the base of the skull to the posterior mediastinum as far as the diaphragm. It is this inferior space which makes the space so dangerous and so important clinically.

Space 4A is the potential space lying within the posterior triangle of the neck between the superficial layer of deep fascia and the scalenus fascia. The most important relationship of this space is inferolaterally with the axilla.

Space 5 is the potential space between the prevertebral fascia and the vertebral bodies extending from the base of the skull to the coccyx. The
commonest clinical example of infection is tuberculous caries of a cervical or thoracic vertebra extending down space 5 transferring infection to the space within the psoas muscle.

**Space 5A** is the space within the posterior triangle deep to the scalenius fascia.

II. Spaces of the Suprathyroid Region

The **submandibular space** includes the regions of the submental and submaxillary triangles lying between the floor of the mouth and the superficial layer of deep fascia. The submandibular space is limited inferiorly at the hyoid bone and inferolaterally at the inferior borders of the stylohyoid and posterior belly of the digastric muscles. Any spread of infection from the floor of the mouth must eventually reach the lateral pharyngeal space which is continuous with space 3 where it can then break into space 4.

The **space of the body of the mandible** is a small potential space between the mandible and the superficial layer of the deep fascia which may become infected secondary to osteomyelitis of the mandible.

The **lateral pharyngeal space** is the important space bounded by the pharynx medially; the mandible, pterygoid and masseter muscles anterolaterally; the parotid gland posterolaterally and the styloid processes and the carotid sheath posteriorly. This space is blind superiorly at the base of the skull but it does communicate with the submandibular space deep to the floor of the submaxillary capsule. There is however free communication between the lateral pharyngeal space and space 3 and thus the danger space 4.

The **masticator and temporal spaces**: The masticator space lies lateral and anterior to the lateral pharyngeal space and contains the masseter, ramus and posterior part of the body of the mandible, the pterygoid muscles, the
tendon of insertion of the temporalis muscle and the inferior alveolar vessels and nerves. It is a completely closed space except superiorly where it is in communication with the space superficial and deep to the temporalis muscle. Perforation between the pterygoid muscles through the intervening fascial wall and into the lateral pharyngeal space or vice versa, can occur.

The parotid space is the name given to the closed space occupied by the parotid gland, the external carotid artery and the posterior facial vein. Careful study shows that there is a complete capsule with the possibility of infection passing into the lateral pharyngeal and submandibular spaces thus making some cases of parotitis life-threatening.

Grodinsky and Holyoke concluded that the understanding of these fascia and fascial spaces in relation to anatomical and surgical orientation and to the spread of infection is very important. Of special clinical interest is the route of spread of infection from the floor of the mouth to the submandibular space, the lateral pharyngeal space, space 3 and danger space 4 in relation to Ludwig's Angina. It was suggested that the degree of danger from infection is dependent upon the location of the portal of entry, the degree of walling off by the inflammatory reaction and the extent of spread before drainage is instituted.

Grodinsky used these anatomical studies in other articles relating to Ludwig's Angina (1939) and to Retropharyngeal and Lateral Pharyngeal Abscess (1939 and 1940) and with Valk (1939) in "The Fascial Spaces of the Neck in Acute Infection".

2.5 Weintraub 1941

The author described "A New Anatomic and Functional Systematization of the Connective Tissues of the Neck". The descriptions were based on his personal observations made in the dissecting room as an instructor in anatomy. He stated that the deep cervical fascia should not be thought of
as a deep connective tissue of single form or function and he presented a new general description of the gross connective tissues of the neck suggesting that there were three surgically important kinds of connective tissue existing in the deeper parts of the neck:

A. Nerve Vessel Connective Tissue of the Neck:
1. Nerve Vessel Bundles: these occupy centre of the stage in each lateral half neck and contain the carotid arteries, the internal jugular vein, the vagus nerve and, depending on the level in the neck, other constituents.
2. Nerve Vessel Sheets: this describes a set of sheets of connective tissue which radiate from the nerve vessel bundle to the skin, muscles, thyroid gland, trachea, oesophagus, pharynx and larynx.

B. Periorgan Connective Tissues of the Anterior Part of the Neck and Associated Periorgan Spaces:

There are numerous anatomic spaces in the anterior or visceral part of the neck, consisting of loose areolar tissue which are bloodless but can undergo oedematous swelling readily and become gelatinous in consistency. The author suggested that because of their topographic position and because of their involvement in pathologic processes, usually in abscess formation, some of these anatomic spaces not otherwise different from the rest have assumed surgical importance and are known as surgical-anatomic spaces. The pharynx was considered to be important structurally with relation to several spaces in the neck, including the peripharyngium which contains two important surgical-anatomic spaces, the right and left peripharyngeal spaces.

C. Interorgan and Intergroup spaces of the anterior part of the neck

1. Interorgan Spaces:

These collections of areolar tissue or spaces lie between organs and occur only and always where there is some relative motion, either inherent or transmitted, between the two organs. Weintraub described numerous
interorgan spaces but did not consider them of great importance. From the point of view of anatomic relationships in surgery they were important in turning aside more superficial organs to expose deeper ones.

2. **Intergroup Spaces:**

   - **the postvisceral space** is the areolar tissue interface between the pharynx and oesophagus and their right and left nerve-sheets anteriorly and the prevertebral muscles posteriorly. This extraordinarily loose space is of extreme importance in pathology and in surgery. It continues through the upper aperture of the thorax into the mediastinum.

   - **the parapharyngeal space** is the collection of fatty areolar tissue lying between the lateral wall of the pharynx medially and the medial surface of the group of muscles of mastication laterally.

Weintraub considered that his systematised division of the connective tissues of the neck was more adequate than the traditional description of the cervical fascia. Iglauer (1941) supported Weintraub's descriptions and the anatomy and pathology of retropharyngeal (peripharyngeal) abscess. The simple "retropharyngeal" abscess which arises from infection of the retropharyngeal lymph nodes usually remains localised within the peripharyngeal spaces. Should the abscess rupture, it might enter the post-visceral space producing a true retropharyngeal abscess or it might perforate laterally and give rise to a parapharyngeal abscess. Iglauer considered the term "peripharyngeal" should be substituted for a simple, uncomplicated abscess situated within the posterolateral wall of the pharynx (mural), and the term "retropharyngeal" should be applied to an extra-mural median abscess. Abscesses originating from caries of the cervical vertebrae were placed in a third category namely "prevertebral abscess" situated in the prevertebral muscle space.
2.6 Tschiassny 1945

Tschiassny supported Weintraub and Iglauer and introduced a new anatomical classification in which he intended to group all the spaces related to the pharynx under the name "Juxtapharyngeal". He described the cross-section of the pharynx schematically as the shape of a "U" consisting of the pharyngeal musculature covered by the fascia pharyngobasilaris at the inner side and the fascia buccopharyngea at the outer side (Figure 14).

The pharyngeal wall is surrounded by several structures which he called the "girdle" structures (G). There are three groups of girdle structures; one in the rear and one on each side of the U. The girdle structures attached to the sides of the U are anteriorly the masticatory system, while the girdle structure at the base of the U is represented by the bodies of the upper vertebrae with the prevertebral muscles attached to it.

Three groups of fascial spaces are described around the upper pharynx. One middle group in the rear (P) is attached to the base of the U while two latent groups (L) are attached to the limbs. Each one of these three groups of spaces includes three rows of almost concentrically arranged subdivisions. They are the inner, the intermediary and the outer rows.

The inner rows are designated as "mural" spaces (M) with two "peritonsillar" spaces for the lateral groups and two "peripharyngeal" spaces for the posterior groups.

The intermediary rows are classified as "extramural" spaces (E) located between the buccopharyngeal fascia and the fasciae of the respective girdle structures. The one in the posterior group is the unpaired "post-visceral" space. The spaces in the right and left lateral group are called lateropharyngeal spaces which consist of an anterior (prestyloid) and a posterior (retrostyloid) compartment.

The outer row forms the girdle spaces (G). These are located within the
FIGURE 14. Schema indicating the arrangement of the fifteen juxtapharyngeal spaces

Note one group in the rear (P) and one on each side (L). Each group includes five spaces in an almost concentrical arrangement. The innermost or mural spaces (M) are: the peripharyngeal for the P group and the peritonsillar for the L groups. The intermediary or extramural spaces (E) are: the postvisceral for the P group and the parapharyngeal for the L groups. The outermost or girdle spaces (G) are: the prevertebral spaces for the P group and the masticatory, parotid and digastric space for the L groups (Tschiassny 1945)
fasciae covering the girdle structures, represented by the right and left prevertebral spaces in the posterior group and by the right and left masticatory, parotid and digastric spaces in the lateral groups.

Tschiassny therefore summarised 15 different juxtapharyngeal spaces in his classification, 5 in the rear and 5 on each side of the pharynx. On the basis of this description Tschiassny presented a diagrammatic composition of five of the commonest juxtapharyngeal suppurations (Figure 15):

1. Peritonsillar
2. Parapharyngeal
3. Peripharyngeal
4. Post-visceral
5. Prevertebral

2.7 Bransby-Zachary 1948 and Gaughran 1957

Bransby-Zachary (1948) noted that the description of the masticator space (Coller et al 1935) included the mandibular ramus and all the muscles of mastication, which would suggest that an infection of this space would lead to involvement of the whole area. However, clinically this does not occur, indicating that the area is divided into compartments. Bransby-Zachary described one of these compartments, the sub-masseteric space and showed its surgical importance in relation to the retromolar fossa, the superficial temporal space and the parotid gland. In order to understand the sub-masseteric space it must be realised that the masseter muscle is divisible into three parts: superficial, middle and deep (Figure 16).

The deep part arises from the zygomatic arch in its whole length. The fibres are short and converge to be inserted into the lateral surface of the coronoid process and the upper one-third of the lateral surface of the ramus.

The middle part arises from the inner aspect of the zygomatic arch in
FIGURE 15. Schematic diagram showing five different juxtapharyngeal abscesses (Tschiasny 1945)
FIGURE 16. Submasseteric space
its anterior two-thirds. The fibres spread out into a thin, almost aponeurotic sheet to be inserted into the lateral surface of the ramus in its middle third as a curved line extending downwards and forwards.

The superficial part, forming the great bulk of the muscle, arises from the lower border of the zygomatic arch in its anterior two-thirds and is inserted by fleshy fibres into the lower one-third of the lateral surface of the ramus as far back as the angle of the jaw.

On the lateral surface of the mandibular ramus associated with the masseter muscle insertions are two "bare areas". One area is behind the insertion of the middle part normally covered by the posterior border of the superficial part of the masseter and a portion of the parotid gland. The second area is in front of the curved insertion of the middle part deep to the aponeurotic sheet and extends as a narrow cleft from the anterior border of the ramus between the middle part of the masseter and the surface of the bone, upwards and backwards between the origin of the middle and deep parts of the muscle from the zygomatic arch. This is the sub-masseteric space. Posteriorly, the space is in close relationship to the parotid gland, being separated from the latter only by a thin fibro-muscular sheet. Anteriorly, it is closely related to the retromolar fossa and is of special importance when considering infections associated with the mandibular third molar.

Gaughran (1957) re-evaluated the fascia of the masticator space, particularly the anterior boundary of the masticator space and described the fascia covering the external surface of the lateral pterygoid and the anteromedial surface of the temporal muscles. He also provided a detailed description of the form and relationship of the fat pad. He concluded that the masticator space is a region bounded by fasciae which restrict the movement of fluid into and out of the space and, as the region is compartmentalised by the fascial planes, the free movement of fluid within
the space is inhibited. These fasciae are related to the muscles of mastication and to the masticatory fat pad which is limited anteriorly by the masseteric fascia. On the basis of the author's studies, the deep temporal, lateral pterygoid and the interpterygoid fascia separate a more medial pterygoid compartment from the more lateral region of the masticator space. The mandibular notch is not an open pathway from the deeper region of the space to the masseteric space and the fat pad is not in direct contact with the spaces of the pterygoid muscles.

2.8 Conclusion

Kostrubala (1945), Burman (1951), Mohiuddin et al (1954) and Snitman and Soboroft (1956) pointed out that haphazard dissection in the loose areolar tissue of the fasciae could lead to the creation of innumerable pockets and fascial layers which do not truly exist as layers until they are created during the course of the dissection. Therefore, it is not difficult to understand how so many fascial planes and layers have been described in the neck when they can easily be created.

Levitt (1976) thought that the confusion in the description of the cervical fascia was due to 2 main reasons:

(i) difficulties in dissecting out fascial spaces anatomically, as false spaces may be created while true spaces are obliterated;

(ii) artificial classification or grouping of spaces for descriptive purposes is difficult and reflects the emphasis of the author. It is the terminology which is confusing and not so much the basic anatomy.

However, it is generally agreed that a knowledge of the cervical fascia is essential in order to understand more clearly the etiology, symptoms, complications and treatment of infections in the orofacial and neck regions. Various authors in the last three decades have provided descriptions of the fascia and fascial spaces of the head and neck, including Casberg (1950),
Shapiro et al (1950), Granite (1976), Paonessa (1976) and Hollinshead (Anatomy for Surgeons, 1968) with most of the information based on the work by Coller and Yglesias (1935 and 1937) and Grodinsky and Holyoke (1939).

2.9 Classification of the Cervical Fascia and Fascial Spaces

(Hollinshead) 1968

Fascia: Superficial and Deep Fascia

A. The Fascia and Fascial Spaces below the Hyoid Bone (Figure 17)

Deep Fascia:

- Superficial layer
  - Middle layer (pretracheal)
  - Posterior layer (prevertebral or retrovisceral) divided into:
    - anterior lamina (alar fascia)
    - posterior (prevertebral fascia)
  - Carotid sheath surrounding the carotid artery, internal jugular vein and vagus nerve is interposed between the superficial, prevertebral and pretracheal layers

Fascial Spaces:

Visceral Compartment divided into

- anterior space = pretracheal or previsceral
- posterior space = retrovisceral, postvisceral, retropharyngeal or retro-oesophageal

Other Spaces

- "Visceral space" = potential space between buccopharyngeal fascia and pharynx/oesophagus
- Visceral-vascular space = potential space within the carotid sheath
- Danger Space or Space 4 of Grodinsky and Holyoke = potential space between alar and prevertebral fasciae
- Prevertebral space = potential cleavage plane existing between the
FIGURE 17. Infrahyoid cervical spaces (axial view)

The investing, middle, and deep cervical fascia divide the neck into compartmental spaces as illustrated. The carotid sheath receives contributions from all three layers. Together with adjacent fat and lymph nodes, the carotid vascular space may be considered the visceral vascular compartment.
prevertebral fascia and the vertebral bodies

B. The Fascia and Spaces above the Hyoid Bone (Figures 18 and 19)

Deep Fascia:

- Superficial layer
- Posterior layer (prevertebral)
- Buccopharyngeal (on the pharynx itself separating the muscular wall of the pharynx from certain potential spaces that surround it)

Fascial Spaces: 3 groups

1. Intrafascial spaces formed by splitting of fascial layers
   - Danger space (between alar and prevertebral fasciae)
   - Space of the body of the mandible
   - Space of submandibular gland
   - Masticator space
   - Parotid space

2. Peripharyngeal Spaces = intercommunicating spaces surrounding the pharynx and lying between fascial laminae and the pharyngeal walls, so that together they actually form a ring around the pharynx.
   - retropharyngeal space (= upper portion of the retrovisceral space)
   - lateral pharyngeal space (= parapharyngeal, pterygopharyngeal, pharyngomaxillary, pterygomandibular or pharyngomasticatory)
   - submandibular space divided by mylohyoid muscle into:
     - sublingual space (above the mylohyoid)
     - submaxillary space (below the mylohyoid)

3. Intrapharyngeal Spaces = potential spaces within the pharyngeal wall deep to the buccopharyngeal fascia
   - peritonsillar space = area of loose connective tissue lying in tonsillar bed
FIGURE 18. Suprahyoid cervical spaces (axial view)
FIGURE 19. Suprahyoid cervical spaces (coronal view)

The investing fascia splits at the mandible into superficial and medial layers forming the masticator space. The masticator space continues superiorly as the temporal space.
2.10 Classification of the Cervical Fascia and Fascial Spaces.

Levitt (1976)

Although the spaces greatly communicate with one another in the spread of infection they are arbitrarily divided into three main groups based on the fact that the hyoid bone is a well situated structure for limiting the spread of infection. The hyoid bone divides the neck naturally into spaces limited to above the hyoid bone and spaces limited to below the hyoid bone. However, because the hyoid bone is limited to the anterior neck only, there are several posterior infections which can spread to involve the entire length of the neck, and this category makes up the third division.

Cervical Fascia

A. Superficial Fascia

B. Deep Fascia
   - superficial layer (investing, enveloping, external and anterior)
   - middle layer (pretracheal, prethyroid, visceral and buccopharyngeal)
   - deep layer (prevertebral, alar and posterior)

Cervical Fascial Spaces

A. Spaces involving Entire Length of Neck

1. Superficial only - superficial space (space 1 of Grodinsky and Holyoke)

2. Deep (Posterior Neck only)
   a. Posterior visceral space also known as retropharyngeal, retrovisceral, retro-oesophageal, retropharyngeal part of visceral compartment and posterior part of Space No. 3 of Grodinsky and Holyoke.

b. Danger Space (Space 4 of Grodinsky and Holyoke)

c. Prevertebral Space (Space 5 of Grodinsky and Holyoke)
   Space within the carotid sheath (visceral-vascular space)
B. Spaces Limited to Above the Hyoid Bone

1. Submandibular Space
   a. sublingual space (superior)
   b. submaxillary (inferior) - submental (central)
      - submaxillary (lateral)

2. Pharyngomaxillary space (or lateral pharyngeal, or parapharyngeal)

3. Masticator space

4. Parotid space

5. Peritonsillar space

C. Spaces Limited to Below the Hyoid Bone (Anterior Neck only)

Anterior Visceral Space: (pretracheal space or prevertebral part of visceral compartment or anterior part of Space No. 3 of Grodinsky and Holyoke).
CHAPTER 3

MICROBIOLOGY OF OROFACIAL INFECTIONS
3.1 Introduction

The oral cavity is accessible to the introduction of many different types of microorganisms. It can be considered an ideal incubator with an abundance of moisture, various foods and differences in oxygen tension so that many aerobic, facultative and anaerobic types find conditions favourable for their growth. The oral ecosystem can be considered as a complex continuous culture which changes as the individual grows and matures. Various sites in the oral cavity represent different microenvironments and therefore support different bacterial florae. The microbial flora that is characteristic of a particular site in a majority of the population is referred to as the indigenous or resident flora (Topazian and Goldberg).

3.2 The Development of the Oral Ecosystem

In utero the foetus is normally germ free, and at birth the oral cavity is usually sterile. Within 8 hours following birth there is a rapid increase in the number of detectable organisms which may include several species of Lactobacilli, Streptococci, Staphylococci, Pneumococci, Enterococci, Veillonella, anaerobic streptococci, Coliforms, Sarcina and Neisseria. At the end of the first year Streptococci, Staphylococci, Veillonella and Neisseriae are generally found in all mouths. The effects of the eruption of teeth provide regions for the growth of microorganisms adapted to environmental conditions around these structures eg. Streptococcus mutans seems to colonize preferentially in plaque. Throughout childhood the bacterial populations increase. The organisms from the gingival crevice area in preschool children resemble those in adults, except the Bacteroides melaninogenicus and Spirochaetes are not present in all children. However, these two organisms are present virtually in all adults. The major factors in establishing and maintaining microorganisms in the oral cavity are bacteria-tissue interactions, interbacterial adherence and interbacterial
interactions. Certain species have a predilection for particular sites in
the oral cavity, probably because some nutritional or physical requirement
is met at that site. As the individual grows older there is a reduction of
Spirochaetes, Lactobacilli and some strains of Streptococci associated with
the loss of teeth. Many other factors also influence the oral flora. The
composition and consistency of the diet, oral hygiene, clinical health and
the use of antimicrobial agents all play a part in determining the
qualitative and quantitative nature of the oral flora (Burnett and Schuster).

One of the most important regulators of the oral microbial flora is
saliva which serves as a culture medium. Diurnal variations in salivary flow
and character cause the density of the oral microbial population to change
with the time of day. Regulatory factors include mineral and ionic content
and balance, buffering capacity, gaseous environment, organic content,
salivary pH, and oxidation-reduction potential (Eh). Aerobic microorganisms
are favoured by a high oxidation potential, while facultative and obligate
anaerobes require a negative Eh. pH influences Eh, the latter becoming more
positive as the pH decreases. Generally, saliva has a high oxidative
potential.

Bacteria are generally classified according to their atmospheric
requirements as obligate aerobes, facultative anaerobes, or strict anaerobes.
**Obligate aerobes** require oxygen for metabolism, that is, they are incapable
of carrying out fermentation. They compose less than 2 per cent of the
supragingival plaque (Manganiello et al 1977) and are a minor component of
the oral flora.

**Facultative anaerobes** can grow in the presence or absence of oxygen and
switch between anaerobic and aerobic energy-yielding pathways, depending upon
the availability of oxygen. Although many members of the oral microflora are
facultative, these organisms are usually adapted to microenvironments with
minimal oxygen. In theory, a facultative organism should be isolated in equal numbers on aerobic and anaerobic plates. However, due to adaptation in situ, approximately twice as many facultatives are isolatable from an oral sample cultured by anaerobic techniques as by aerobic techniques (Manganiello et al 1977).

Strict anaerobes are organisms that cannot grow in the presence of oxygen. Metabolism occurs via fermentative processes, for example, glycolysis, or anaerobic respiration, which employs terminal electron acceptors other than oxygen. Anaerobes can grow in saliva because of the presence of reducing substances, so there may be a continual drift toward a negative Eh. Also, the anaerobes are found in areas where there is less salivary flow; hence the lower Eh levels which favour these organisms tend to persist. For example, the gingival crevice area has Eh levels that range from about +100 to about -300 mv.

Although Louis Pasteur is generally credited with the discovery of anaerobic bacteria in 1861, the role of these organisms in clinical infections was not appreciated until the classic studies of Veillon and Zuber in the late 1800s. The initial studies of anaerobic bacteria in dental infections date to the early 1900s when there were numerous reports of "fusospirochaetal disease". In 1905 Vincent reported the frequent observation of fusiforms and spirochetes in "dental periostitis". Baugartner noted these same morphotypes in putrid exudates obtained from necrotic tooth pulps in 1908. Later, similar observations were made with alveolar abscesses and acute necrotizing ulcerative gingivitis (ANUG). More than 100 anaerobic bacterial species have now been identified in the oral cavity. The anaerobic bacteria that colonise retentive oral sites are different from those found in the gingival plaque. The healthy gingival sulcus harbours relatively few anaerobic microorganisms. However, the development of gingivitis is followed
by an increased population of anaerobic microflora. The gingival sulcus forms a relatively stagnant environment, where bacteria that cannot adhere to the surface of the tooth may colonise. The development of subgingival plaque starts with the colonisation of facultative anaerobic gram-positive bacteria which attach strongly to the tooth surface and can resist the rinsing effect of saliva and gingival fluid. The anaerobic gram-negative rods then attach to the gram positive cells and begin to colonise the periodontal pocket (Socransky and Manganiello 1971).

The accompanying table (Table 2) by Burnett and Schuster (1983) shows the distribution of the important groups of indigenous microorganisms found in the head and neck region.

3.3 The Nature of Parasitism

Parasitism is a natural phenomenon associated with all microorganisms. The initial contact between host and microorganism may result in a transient relationship in which the intruder is destroyed or removed by the host’s defence mechanisms, either immediately or after temporary residence. A number of microorganisms are facultative parasites and lead a saprophytic existence as long as they remain in their accustomed locations. However, they may become pathogenic if the host adaptation breaks down. This involves migration of a parasite from its usual habitat to an unaccustomed site, where it behaves as a pathogen, as for example in the transfer of normal "harmless" inhabitants of the oral cavity into the deeper tissues, resulting in a soft tissue or bone infection.

To cause disease, a microorganism must be able to do all the following: enter the host, multiply on or in the host tissues, resist or not stimulate host defenses (at least temporarily) and damage the host. Each process is complex, involving several determinants. Lack of any one may result in a considerable attenuation of pathogenicity.
### Table 2: Distribution of Important Groups of Indigenous Microorganisms in the Head and Neck Region

Burnett and Schuster (1983)

<table>
<thead>
<tr>
<th>Organism</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mouth</td>
</tr>
<tr>
<td>Gram-positive facultative cocci</td>
<td></td>
</tr>
<tr>
<td>α-Streptococcus</td>
<td>++++</td>
</tr>
<tr>
<td>β-Streptococcus</td>
<td>+</td>
</tr>
<tr>
<td>Nonhaemolytic Streptococcus</td>
<td>+++</td>
</tr>
<tr>
<td>Pneumococci</td>
<td>+</td>
</tr>
<tr>
<td>Staphylococcus epidermidis</td>
<td>+++</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>+++</td>
</tr>
<tr>
<td>Gram-positive anaerobic streptococcus</td>
<td></td>
</tr>
<tr>
<td>Peptostreptococcus</td>
<td>+++</td>
</tr>
<tr>
<td>Gram-positive facultative rods</td>
<td></td>
</tr>
<tr>
<td>Diphtheroids</td>
<td>++++</td>
</tr>
<tr>
<td>Lactobacillus</td>
<td>+++</td>
</tr>
<tr>
<td>Actinomyces</td>
<td>+++</td>
</tr>
<tr>
<td>Gram-positive anaerobic rods</td>
<td></td>
</tr>
<tr>
<td>Clostridium</td>
<td>+</td>
</tr>
<tr>
<td>Diphtheroids</td>
<td>+++</td>
</tr>
<tr>
<td>Organism</td>
<td>Site</td>
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<tr>
<td>---------------------------------------</td>
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</tr>
<tr>
<td></td>
<td>Mouth</td>
</tr>
<tr>
<td>Gram-negative facultative cocci</td>
<td></td>
</tr>
<tr>
<td>Neisseriae</td>
<td>+++</td>
</tr>
<tr>
<td>Gram-negative anaerobic cocci</td>
<td></td>
</tr>
<tr>
<td>Veillonellae</td>
<td>+++++</td>
</tr>
<tr>
<td>Gram-negative facultative rods</td>
<td></td>
</tr>
<tr>
<td>Pseudomonas</td>
<td>+</td>
</tr>
<tr>
<td>Coliform bacteria</td>
<td>+</td>
</tr>
<tr>
<td>Gram-negative anaerobic rods</td>
<td></td>
</tr>
<tr>
<td>Fusobacterium</td>
<td>+++</td>
</tr>
<tr>
<td>Bacteroides</td>
<td>+++</td>
</tr>
<tr>
<td>Spirochetes</td>
<td>+++</td>
</tr>
<tr>
<td>Yeasts</td>
<td>+++</td>
</tr>
</tbody>
</table>

++++ = Generally present as major component of cultivatable flora
+++ = Generally present as minor component of cultivatable flora
++  = May be present as major component in carriers
0    = Not normally present
Infections of the head and neck are of odontogenic and non-odontogenic origin. Odontogenic infections are the most common and arise from the involvement of the pulp and periapical regions, periodontal disease and pericoronal infections.

Bacteria are the principle source of pulpal infection and they invade the pulp whenever they are given the opportunity. The inflammatory response of the pulp to severe or acute irritation is recognized by chronic or acute pulpitis which if severe enough may progress to tissue necrosis and death. The periapical tissues may become involved with the infecting microorganisms and their products, and infection may ultimately extend into the soft tissues of the head and neck. These infections are of the mixed variety and include both aerobic and anaerobic bacteria with estimates of the anaerobic content between 30% to 50%. The most common bacteria are the alpha and non-haemolytic Streptococci.

Periodontal abscesses usually occur after a period of chronic periodontitis. Deep periodontal pockets are exceptionally favourable sites for growth of virulent microorganisms particularly anaerobes.

Pericoronal infections associated with the eruption of teeth, most commonly the wisdom teeth, are usually initiated by Streptococcal and Staphylococcal infections, though any members of the oral flora may be involved.

Non-odontogenic infections may arise from intraoral or extraoral sources. The causative organisms enter through microscopic as well as macroscopic breaks in the skin or mucosa, or they may be introduced by injection, surgery or trauma. They may also be introduced by infections of the skin, mucosa, nose, sinuses, tonsils and salivary glands. Non-odontogenic infections will enlarge and spread in the same way as those of odontogenic origin (Topazian and Goldberg).
3.4 The History of the Microbiology of Orofacial Infections

Head and Roos (1913 and 1919) were interested in the bacteriology of "pyorrhea" and of dental apical abscesses. They hoped to encourage more research in this important field especially among investigators who had access to clinical material and laboratory facilities and had the necessary technical expertise.

These authors studied 350 patients with oral infections associated with pyorrheal pockets and found the following aerobic microorganisms in the following percentage of patients: Streptococci, 95%; Gram negative cocci of the M. catarrhalis group, B. influenzae, and other Gram negative bacilli of the hemophilic group, ~80%; Pneumococci, Staphylococci and bacilli of the Diphtheroid group; in a percentage sufficiently large to indicate their probable importance.

Head and Roos also examined 130 specimens of root apices of extracted teeth from 100 patients and found Streptococci in 124 of these specimens and a minute Gram negative strictly anaerobic, cocco-bacillus in 90 specimens (invariably in symbiosis with the Streptococci). They suggested that the great toxicity that was evident in laboratory animals infected with this Gram negative anaerobic cocco-bacillus in symbiosis with streptococci, could account for the severe systemic disturbances so frequently associated with oral infections.

Studies by Hartzell and Henrici (1915), Moody (1916) and Lucas (1920) found a variety of organisms in chronic alveolar infections but Streptococcus viridans was the predominant organism. Smith (1919) investigated dental infections in children and found Streptococci of all types, Pneumococci and Staphylococci.

Fraser’s study (1923) showed that S. viridans occurred in 90% of oral infections. He believed that it was the primary infecting organism in all
patients with periapical abscesses, but added that secondary infection with other types of organisms frequently occurred. He attempted to correlate the bacteriological findings with the X-ray and clinical picture and suggested that, if the X-ray showed a small radiolucency at the apex of the tooth then *S. viridans* could usually be isolated as a pure culture.

Haden (1926) was interested in the bacteriological status of pulpless teeth and cultured the apex and periapical tissues from 1500 teeth (including both vital and non-vital teeth) so that contaminating organisms could be identified. Streptococci were present alone or mixed with other organisms in 92.5% of positive cultures. The most common organism was the non-haemolytic Streptococci and the most common types were *S. faecalis*, *S. mitis* and *S. salivarius*. Haden also compared radiographic evidence of apical infection with the bacteriological evidence and thought it was noteworthy that the radiographic negative group showed nearly as high an incidence of bacteriological infection as the radiographic positive group.

Bulleid (1928 and 1931) found that the bacterial population of pathogenic importance in apical granulomas consisted of various species of Streptococci occasionally in symbiosis with Staphylococci. He also studied acute alveolar abscesses and jaw cysts and always found various species of Streptococci present.

Hyde (1933) discovered that in the majority of his patients with cervical cellulitis, the organism most frequently encountered was the Staphylococcus. However, in his patients with Ludwig's Angina, he found a mixed infection with Streptococci predominating.

Alden (1936) also found many types of organisms in cervical infections but in those in which the abscess was secondary to oral or dental infection the *Borrelia vincenti* was the predominant organism.

Meleney (1938) made extensive bacteriological studies of the purulent
material obtained from cervical infections secondary to oral abscesses. He found oral commensals including non-haemolytic Streptococci together with the fusiforms and *Borrelia vincenti*.

Taffel et al (1942), McCaskey (1942), Williams and Guralnick (1943) Seley (1947) and Beck (1952) also found Streptococci present in their studies of odontogenic infections.

Ludwig (1957) undertook an investigation to attempt to define the bacterial flora of various suppurative oral swellings of dental origin. The results from 192 specimens indicated that the majority of the oral infections were mixed infections with the bacterial population resembling that of the normal oral flora. However, the two most common bacteria isolated were *Streptococcus viridans* and *Staphylococcus albus* though the spirochaetes and fusiform bacilli were also significant. The most common microorganism isolated by cultivation was *S. viridans*, however *S. albus*, non-haemolytic Streptococcus, coliform bacilli, Neisseria and Diphtheroids were almost invariably present. It was also observed that a number of acute dentoalveolar abscesses were apparently sterile. This fact, in conjunction with indications of the low grade pathogenicity of the microorganisms, led to the suggestion that these bacteria were relatively harmless saprophytic invaders, rather than the agents primarily responsible for the infection. Alternatively, the work of Rosebury (1950) and Holm (1950) suggested that, while the pathogenicity of each type of microorganism is low, it may be enhanced by a combination of the different types of bacteria.

Throughout the 1950s and 1960s there continued to be many reports of orofacial infections in the literature with the consensus of opinion that the occurrence of mixed isolates in these infections was common. Streptococci were recovered in the majority of infections with the presence of gram negative organisms in foul smelling pus. It was thought that with the
increasing use of appropriate media more anaerobic organisms would be isolated in the future.

Goldberg (1970) reviewed the changing biological nature of acute dental infection and undertook a study of 93 consecutive patients who had dentoalveolar infections. He noted that the bacteriological spectrum of infection had changed since the introduction of penicillin, together with the emergence of antibiotic resistance in microorganisms. Prior to the antibiotic era, most instances of dentoalveolar abscesses were caused by Streptococcal organisms. Initially, penicillin had almost proved to be a panacea against these organisms. More recently, Goldberg has noted the emergence of an increasing number of gram negative infections. In his study, the presence of pathogenic organisms was observed in 92 of 93 specimens. Of interest was the increase in gram negative rods including both Pseudomonas and Proteus species. This study demonstrated that distribution of microbiological flora in oral infection is not static but is continually evolving into new patterns of distribution and, therefore, the surgeon must continue to submit specimens for culture and sensitivity studies so that correct antibiotic therapy is applied.

Goldberg (1971) reported on a post extraction infection associated with the gram negative organism *Mimae polymorpha*. Although described as normal flora in the pharynx, it is an unusual organism to be found in the oral cavity. *Mimae* are opportunistic organisms which produce penicillinase and display a highly variable virulence. The organism invades only where there is an open wound or weakened host resistance. *Mimae* are typical of the changing ecology of bacterial infections and their diagnosis is dependent on the alertness and awareness of the clinician and laboratory personnel.

Sabiston and Gold (1974) relegated the use and selection of antibiotics to an adjunctive and empirical position in the overall management of
orofacial infections. Their data indicated that oral abscesses contained a variety of obligate anaerobes, many showing resistance to a wide variety of antibiotics including penicillin.

Sims (1974) noted that purulent infections of the oral cavity were an everyday occurrence, and that many dental surgeons dealt with infection successfully without ever knowing which bacteria were involved. He considered this quite unacceptable. Sims analysed 1000 consecutive specimens of pus from oral infections for the presence of known pathogens and assessed whether organisms of the normal flora were present in normal proportions. This was achieved by a Gram stain, aerobic and anaerobic culture, and by setting up a primary antibiotic sensitivity plate. The most commonly found organisms included *Streptococci viridans*, *Staphylococci epidermis* and *Neisseria spp*. Although all these organisms were isolated from the pus, it did not necessarily mean that they were responsible for the pus formation. Pus forms whenever polymorphs fail to remove the irritant which is provoking the inflammatory response and healing will only occur when the pus is removed. The majority of organisms in the oral cavity are not pathogenic but their growth in a local or systemically compromised situation will proliferate and produce serious disease.

Sprinkle et al (1974), though agreeing with previous authors that *Staphylococcus aureus* and *Streptococci* were most commonly associated with abscess formations in the head and neck, believed that insufficient consideration had been given to the anaerobic bacteria, primarily *Bacteroidaceae*.

Turner et al's study (1975) of an outpatient population with soft tissue abscesses secondary to dental caries showed *Streptococcus viridans* was the dominant organism, though the variety of associated organisms warranted culture and sensitivity testing of the isolates. Most of the organisms
showed a favourable *in vitro* response to antibiotics commonly recommended for use in the management of dental infections. Turner questioned the role of anaerobes in such infections. Are the anaerobes primary pathogens or contaminants or are they able to produce disease by some unique cooperation with the other organisms? Antibiotic therapy is directed towards likely pathogens in any given clinical infection and any additional recommendations concerning antibiotic therapy should include close evaluation of the patient's present illness, observation of the consistency and odour of the exudate and the gram stain. The authors considered that most anaerobes show sensitivity to penicillin *in vitro* but importantly, the initial management with surgical drainage changes the environment and discourages the continued proliferation of the anaerobic population.

Sabiston et al (1976) reviewed exudates of 65 dental abscesses which had extended beyond the alveolus to cause obvious erythematous fluctuant swellings. These were cultured carefully for obligate anaerobes and the species identified were essentially those found in the mouth in the absence of infection. This supported the proposition that oral abscesses are caused by opportunistic pathogens whose presence, under other circumstances, could be consistent with clinical health. The cultures yielded a mixed anaerobic population which was of interest as the data indicated that most of the species isolated were incapable of producing infections alone. However, abscesses from which a single species was isolated were, with one exception, all apparently caused by facultative Streptococci. The authors considered that anaerobic techniques were essential in the study of pyogenic oral infections and further study into the role played in a mixed infection by a given isolant was needed.

Bartlett and Gorback (1976) summarised the available information concerning "Anaerobic infections of the Head and Neck", and provided
guidelines for diagnosis and antimicrobial treatment. In order to confirm
the diagnosis the anaerobic pathogen must be recovered from a suitable
clinical source. This required the consideration of 3 criteria:

- collection of appropriate specimens
- expeditious transport to the laboratory
- proper bacteriological processing

The authors reported that the major anaerobic pathogens identified in head
and neck infections were Peptostreptococci, Bacteroides melaninogenicus and
Fusobacteria.

Sabiston and Grigsby (1977) similarly emphasised the importance of
acquiring information on the anaerobic bacteria involved in "dental-pyogenic"
infections, stressing that accumulation of data was important for future
infections, because empirical selection of antimicrobial agents could be
based on experience with a given species. Their findings supported the
conjecture that oral absceses were caused by opportunistic pathogens whose
presence under other circumstances would probably be innocuous.

As the majority of oral infections respond well to adjunctive treatment
with antibiotics, it is only when this form of therapy is not so successful
that the usefulness of laboratory culture and sensitivity testing is
appreciated. Occasionally, an organism such as Eikenella corrodens, a
facultative anaerobic gram negative rod, which is a weak opportunistic
pathogen may produce a severe infection. Its proliferation is dependent on
the presence of other organisms which invade the traumatised tissue and
deplete the available oxygen. As the area of tissue necrosis increases, the
blood vessels at the periphery become occluded, thus diminishing the
vascularity and oxygen transport to the area. This not only allows the
organism to flourish but also impedes antibiotics from reaching the site of
infection. This may explain why the organisms in vitro sensitivity is found
to be ineffective in vivo. Oral infections with *Eikenella corrodens* have been reported by Goodman (1977), De Mello (1979) and Stiesler (1979).

Chow and Brady (1978), in their review of orofacial odontogenic infections, noted that in most of their patients if anaerobic culture techniques had not been employed, only streptococci would have been recovered. They also showed that various "spreading or invasive factors" could be produced by both oral Streptococci and obligate anaerobes which included endotoxins such as collagenase, fibrinolysins, neuraminidase, phosphatase, lipase, protease, elastase, hyaluronidase, chondroitin sulphatase, ribonuclease and deoxyribonuclease.

Other studies by Bartlett (1979), Geisler (1979), Greenberg (1979), Kannangara (1980), Von Konon (1981), Woods (1981), Aderhold (1981), Hol (1981), Oguntebi (1982), Hunt (1983), Labriola (1983), Williams (1983), Morey (1984), Johnson (1984), Heimdahl (1985), Young (1985), Lewis (1986), Gridley (1986) and Sklavounos (1986) also confirmed the polymicrobial nature of orofacial infections, in particular, the presence of anaerobic organisms. Reports of severe facial infections associated with gas-producing bacteria were reported by Gonty (1981), Heidelman (1982) and Schroeder (1987). Gas may be introduced into tissue by extrinsic factors such as severe trauma and improper irrigation of wounds or intrinsic factors such as infection caused by aerogenic organisms. Gas in the head and neck region has been reported as a result of non-clostridial organisms. They are usually due to mixed infection and, though not as severe as those due to Clostridia, they still have a morbid prognosis unless treated vigorously. *Bacteroides melaninogenicus* is known to be aerogenic, though the presence of other organisms may contribute to its ability to form gas.

Hunt and Meyer (1983) reported on the continued evolution of the microbiology of oral infections and stated that acute infections involving
the oral cavity continued to trouble dental clinicians. Failure to identify
the causative organisms and select an effective antibiotic were frequent
management problems. Anaerobic bacteria were becoming more prevalent and
difficulties would also arise as antibiotic-resistant strains emerged.
Therefore, selection of an appropriate antibiotic was largely dependent on
culturing and antibiotic susceptibility testing. The authors noted an
increase in Bacteroides and this paralleled the general trend towards
increased incidence of gram negative organisms reported elsewhere. These
infections are clinically important because they often occur in previously
healthy individuals and rapidly fulminate. Therefore, there is a continuing
need to recognise the changing bacteriology and antibiotic susceptibilities
of orofacial infections.

Labriola (1983) reported a marked increase in penicillin resistant
organisms involved in orofacial abscesses. However, it must be remembered
that in vitro resistance does not equate with in vivo resistance particularly
in mixed infections. Labriola’s study acknowledged that patients were
usually cured, or well on the way to recovery before it was determined on the
basis of laboratory testing that one or more infecting organisms was
resistant to penicillin. While removal of the cause of infection and
surgical drainage are of paramount importance, the use of proper anaerobic
culturing techniques may later prove useful in identifying the organisms and
in selecting the appropriate antibiotic for treatment of the more
recalcitrant orofacial infections that do not respond to standard therapy.

Heimdahl et al (1985) investigated 58 patients with acute orofacial
infections of odontogenic origin. These patients were classified into two
groups with respect to the severity of their infection. Mild infection was
considered to be present when the patient’s body temperature was below 38°
and the infection was limited to the alveolar process, or extended outside
the alveolar process without engaging adjacent anatomic spaces, and without causing significant trismus, swelling or pain. Severe infections were considered present when the body's temperature was above 38° and the infection extended outside the alveolar process involving adjacent anatomical spaces, or caused significant trismus, swelling or pain. Specimens of pus were obtained by aspiration and all patients were cured by surgical drainage and antibiotic therapy. In the group of 24 patients with mild infection, 18 had only anaerobic infections and 6 mixed infections, while the group of 34 patients with severe infections, 20 had anaerobic infections while 14 had mixed infections. Since aerobic bacteria were more frequently isolated from patients with severe infections, it was thought they played a part in lowering the reduction-oxidation potential, thus enhancing an anaerobic infection, whereas in the mild infections the aerobic organisms isolated contributed less to the development of anaerobic infections.

Lewis et al (1986) claimed that quantitative information is required to fully understand the pathogenesis of mixed infection in the orofacial region and the implication of this treatment. In his study, Lewis investigated 166 isolates from 50 abscesses. 74% of the strains obtained from these isolates were strict anaerobes and 26% were facultative anaerobes. The spectrum of organisms isolated was very similar to that noted in other reports, the anaerobic species most commonly isolated being Peptostreptococcus and Bacteroides. This study supported the concept that the early phase of abscess formation involved Streptococci which prepared the environment for subsequent anaerobic invasion. In conclusion, viable bacteria were present in large numbers in dentoalveolar abscesses that had progressed to fluctuant swellings and the bacterial load was predominantly anaerobic.

3.5 Anaerobic Infections

The principal anaerobic organisms causing disease in man are all members
of the indigenous flora and it seems reasonable to suspect that changes in
the host defences and the selective pressures on the normal flora allow a
proliferation of the anaerobic organism. It should be emphasised that many
clinical infections are unrelated to anaerobes and others may harbour
anaerobes as harmless commensals. An antibiotic effective against anaerobes
should not be considered a panacea as surgical drainage is often the most
compelling consideration. In addition, appropriate use of an aminoglycoside
or other drug effective against concomitant aerobic pathogens is an important
adjunct to successful treatment (Anderson 1976).

In the past most clinical laboratories lacked the technical competence
to grow fastidious anaerobes. It was generally believed that these organisms
were only rarely involved in human disease. Certain types of anaerobic
bacteria command special attention since they produce toxins that cause
characteristic effects such as tetanus and gas gangrene. More attention has
now been given to the septic processes associated with anaerobic
microorganisms in the normal flora. Since many infections by anaerobes also
contain aerobic or facultative bacteria, the latter easily outgrow the slower
growing strict anaerobes making the detection and isolation of the anaerobes
difficult or impossible. Since laboratory investigation has been directed
towards isolating both aerobic and anaerobic organisms, improved technology
has allowed the culture of highly fastidious anaerobes from clinical
material.

The concept that a single organism may be responsible for a specific
disease does not apply to anaerobes. It has been found that septic processes
harbour multiple strains of microorganisms with varying oxygen sensitivities
and that the bacteria behave in a cooperative fashion to produce sepsis.
Other means of synergistic activity may include providing growth factors or
the production of tissue-destructive enzymes.
Necrotic infections within the oral cavity are always associated with Bacteroides species particularly *Bacteroides melaninogenicus* or anaerobic Streptococci, Spirochaetes or Fusiforms. When *B. melaninogenicus* is deleted from recombinations of pure cultures, the remaining mixtures (including Spirochaetes, Fusiforms, anaerobic cocci and Diphtheroids) are usually non-pathogenic. Other strains of Bacteroides, Fusobacterium and motile gram negative anaerobes could be admitted, and infection would still occur, though less frequently or in an attenuated form (MacDonald et al 1963).

*B. melaninogenicus* is a small, gram negative, anaerobic, non-sporulating black pigment-producing rod which was first isolated in 1921 by Oliver and Wherry. Weiss (1943) suggested that it should be regarded as an "opportunist" which is capable of producing disease when given a favourable opportunity to enter the tissues or when the natural resistance to infection is abnormally low. *B. melaninogenicus* is a regular inhabitant of the oral cavity of man particularly in the gingival crevice. Most strains require hemin for growth, and half the isolates require an analogue of Vitamin K. It is capable of hydrolysing native gingival collagen and is the only indigenous organism of the mouth that has been shown to have this property. Weiss showed that *B. melaninogenicus* accompanied by two other Bacteroides strains and a facultative Diphtheroid, produce typical necrotic abscesses. It appears that the facultative Diphtheroid produces a required growth factor, presumed to be naphthoquinone. Bronstein (1964), Socransky (1965), Dormer (1972), Gorbach (1974), Leake (1972), Monaldo (1974), MacDonald (1963), Bartlett 1976, Gross 1976, Finegold 1975 and 1977, Heimdahl 1980, Van Winkelhoff (1988), Sundqvist (1979), Linder (1980), Bahn (1981), Gaustad (1983), Busch (1984), Carter (1984), Van Steenbergen (1984) and Brook (1986) all reported on orofacial infections involving anaerobic organisms.

Quayle (1974) reviewed the literature on Bacteroides, noting that there
was increasing evidence that the incidence of anaerobic infections due to Bacteroides species was much greater than had previously been recognised. However, it was difficult to determine whether the Bacteroides were primary pathogens or contaminants. Since the organisms are slow growing and difficult to culture, it was considered likely that some specimens were disposed of before the organisms developed on the culture medium. It was thought that *B. melaninogenicus* are "almost invariably present in any foul smelling material from the mouth". Quayle stated that a provisional clinical diagnosis of Bacteroides infection could be made:
- whenever many gram negative rods were present in a smear of pus of dental origin,
- when the pus emitted a foul odour or when gas was present in the lesion,
- when local tissue necrosis was occurring,
- when local thrombophlebitis developed,
- when the patient was already debilitated for example by surgery, cancer, or by the use of cytotoxic drugs or radiotherapy.

Quayle noted that antibiotics played an important role, but that the literature was confusing as to the correct choice. Penicillin was generally considered to be satisfactory even though oral strains of Bacteroides which demonstrated *in vitro* sensitivity did not always reflect the same sensitivity in clinical situations. Recent studies had shown Bacteroides to be highly sensitive to clindamycin and this had been recommended as the drug of choice by some authors. Quayle, however, suggested the following treatment plan in the management of moderate to severe infections in the orofacial region:
- immediate institution of empirical antibiotic therapy (Quayle advocated clindamycin/lincomycin),
- immediate surgical intervention to establish drainage of pus with the removal of necrotic tissue,
gram stain of a smear of pus, looking for gram negative rods,
aerobic and anaerobic culture of the pus,
sensitivity tests on the organisms thus isolated,
repeated culture and sensitivity tests for patients that do not respond rapidly to antibiotics and drainage.

3.6 Conclusion

The successful management of orofacial infections usually requires surgical incision and drainage and the selection of an antibiotic which depends on the isolation and identification of the infective organisms. The pathogenesis of most infections of the face and jaws is related to non-vital or periodontally involved teeth or to pericoronial infections of impacted teeth. The studies of this century have recognised the complexity of the microbiological flora inhabiting the oral cavity and their synergistic activity in causing orofacial infections when the opportunity is available. Though the common aetiological agents are known there is always a need for recognition that atypical organisms may cause "classical" infections. By obtaining cultures before the commencement of antibiotics and with aggressive airway and surgical management it should be possible to achieve a successful outcome and lower mortality of these serious infections.
CHAPTER 4

DIAGNOSTIC TECHNIQUES
4.1 Laboratory Diagnostic Techniques

4.1.1 Introduction

In general, a clinical diagnosis of any infectious disease should be confirmed by laboratory methods before beginning treatment. However, some delay invariably occurs so therapy is usually begun while awaiting results of laboratory determinations. The specimen needs to be representative of the situation at the site of infection. Therefore, the site should be prepared in order to eliminate contamination of specimens with indigenous and colonising bacteria. Invasive procedures may be required when the site of infection is deeply situated. Initial treatment may be guided by reviewing reports of specimens that have been submitted from similar sites from other patients with similar conditions and problems. The susceptibility of frequently isolated bacteria to commonly used antimicrobial agents is now well established. To maximise the information gained by laboratory examination, the collection of the most appropriate specimen by the most efficient means and its optimum transport to the laboratory are required (Topazian and Goldberg).

4.1.2 Identifying the Oral Microflora

The microflora of the oral cavity consist of bacteria, yeasts, fungi, mycoplasmas, protozoa and viruses. Each of these microbial types are characterised by morphological and physiological principles, and to study these, two basic techniques are employed:

- the direct smear and the culture plate.

In the first technique direct smears are made on glass slides, stained with crystal violet (Gram's method) and observed under the microscope. The Gram stain smear can be very useful in establishing whether the site has been properly prepared to remove contamination prior to collecting the specimen. The presence of neutrophils and an absence of squamous cells indicate an
inflammatory exudate has been collected and that it is uncontaminated by material from the skin and the mucous membranes. Conversely, an abundance of squamous cells and an absence of neutrophils indicate that the bacterial population present will almost certainly represent indigenous flora of the mouth or skin.

The Gram stain not only differentiates gram positive and gram negative bacteria but separates those that are clearly rod-shaped from those that appear as cocci. It also distinguishes those that have a filamentous appearance (Actinomyces) from the yeasts which appear as budding cells or demonstrate pseudohyphae. The Micrococi, Staphylococci and Streptococci appear as spherical gram positive staining organisms. The gram negative cocci are typified by the Neisseria and Actinobacter species. Exceedingly small gram negative cocci suggest the anaerobic Veillonella. The gram negative rods constitute a large number of pathogenic species but can be subdivided morphologically into three general categories, the Enterobacteriaceae, the Pseudomonas, and the smaller and more pleomorphic rods, chiefly the Bacteroides and Haemophilus groups. Anaerobic infection is typified by an abundance of small coccal or rod-shaped gram negative bacteria with an admixture of gram positive cocci. Therefore, the direct smear technique gives certain information regarding the basic morphological types of bacteria involved in an infection.

To determine the exact identification of the microorganisms and to test for antimicrobial susceptibility a second basic technique, the culture plate, is employed. The majority of orofacial infections are caused by bacteria, and their cultivation is most readily accomplished on simple artificial media. The samples may be streaked directly onto enriched culture media or onto selective media and these streaked plates allow for qualitative evaluations of the types of microorganisms present (Plate 1). Enriched
media are used to give the total number of cultivatable microorganisms or colony-forming units (C.F.U.), whereas selective media are used to determine the presence and number of various types of specific oral microorganisms. To determine the total numbers of cultivatable microorganisms, cultures should be incubated under both aerobic and anaerobic conditions. The majority of microorganisms cultivated from the oral cavity are neither strict aerobes nor strict anaerobes. The use of selective media and specific biochemical tests aid in the identification of various genera and help differentiate the various species of genera (Doku 1974; Rosenblatt 1977).

4.1.3 Collection and transport of specimens

Specimens representative of the site of infection should be collected in an amount sufficient for both direct examination and culture. Unsuitable containers may allow contamination of the specimen or drying of the specimen with the loss of viability of fastidious organisms.

Proper preparation of lesions exposed to oropharyngeal and orocutaneous flora requires rinsing or irrigation with water or saline. Fluid or exudate can be collected with a spatula that may be inserted into a sterile tube, or specimens can be aspirated from superficial or deep lesions with a syringe. Swabs can be used, though cells, bacteria and especially fungi become entrapped among the fibres and may not be recoverable for examination or culture (Plate 2). Swabs should always be handled in a transport container that prevents drying and protects anaerobic bacteria from oxygen so as to retain the more fastidious organisms in viable form. When enlarged and potentially infected lymph nodes are encountered, or tissue is removed from a site that may be infected, specimens should always be submitted for both histological and microbiologic examination. Too frequently the entire specimen is fixed in formalin, and subsequent histological examination reveals only nonspecific inflammation. The aetiology cannot be determined
PLATE 1. Microbiological culture plate.

PLATE 2. Microbiological culture swabs.
satisfactorily without microbiological examination of fresh tissue.

4.1.4 Blood cultures

Whenever patients demonstrate evidence of systemic sepsis, suggesting that an infection has extended beyond the confines of the oral and maxillofacial region, blood samples should be collected for culture. Bacteraemia, the dissemination of bacteria in the blood stream, can be derived from acute orofacial infections. The highest number of microorganisms in the bloodstream are found just before the spiking of fever, when the temperature begins to rise, or immediately after chills. Blood cultures should be taken prior to institution of antibiotic therapy as these drugs might suppress the microorganisms and inhibit their growth in culture. As blood samples are easily contaminated during collection, more than one sample should be collected for culture. Blood cultures should be incubated for 7 days though most will become positive within the first 48 hours.

4.1.5 Laboratory Tests Used to Guide Antimicrobial Therapy

Laboratory tests that can be helpful in guiding antimicrobial therapy include:

- antimicrobial susceptibility testing
- determination of bacterial beta-lactamase production
- assay of serum inhibitory and bactericidal activity
- assay of specific antibiotic levels in serum

The clinical response of a patient who has an infection depends on such factors as the patient’s age, presence of immunocompromising disease or therapy, extent and location of the infection, necessity for surgical drainage, adequacy of antimicrobial dosage and diffusion into the infected site and susceptibility of the infecting bacteria to antimicrobial agents.

Assessing antimicrobial effectiveness

In vitro antimicrobial susceptibility tests include the disc diffusion
tests developed by Bauer and his associates (Plate 3). It is possible to
differentiate isolates into broad categories of susceptibility (S) and
resistance (R) with an intervening zone of indeterminate susceptibility (I).
These are based on the correlation of the minimum concentration that inhibits
growth in vitro by a dilution method with zone diameters obtained from large
numbers of isolates. The same techniques which have been found useful for
testing rapidly growing facultative bacteria have been utilised, with
substantial modification, in an attempt to provide clinically useful
information on the antibiotic susceptibility of anaerobes. Modifications
have involved additional nutritional supplements in the growth medium which
provide for decreased oxidation-reduction potential. Disc sensitivity
testing of anaerobes has been carried out, but is only really applicable to
the rapidly growing anaerobes. Also anaerobiosis affects the activity of some
antibiotics, in some cases increasing the activity and sometimes decreasing
the activity.

Broth dilution or agar dilution tests are considered more reliable.
These tests involve inoculation of a series of tubes or plates with a range
of antibiotic concentrations. The lowest concentration of antibiotic which
prevents bacterial growth is designated the minimum inhibitory concentration
(M.I.C.). Simpler and more rapid methods have been developed. Wilkins and
Thiel described a method whereby commercial antibiotic discs are added under
anaerobic conditions to tubes of pre-reduced broth medium to achieve a
concentration of antibiotic approximating that attainable in blood.
Resistance or susceptibility to antibiotic is determined by comparing growth
in the presence of antibiotic with that in the absence of antibiotic. A
good correlation has been observed between results obtained by broth, disc
and M.I.C.s. The minimum bactericidal concentration (M.B.C.) may be
determined by subculturing to determine the concentration that kills at least
DIRECT SENSITIVITIES ARE PERFORMED

BY PLACING ANTIBIOTIC DISCS ON A PLATE

WHICH HAS BEEN SEEDED WITH ORGANISMS

ZONES OF INHIBITION INDICATE

ANTIBIOTIC SENSITIVITY

PLATE 3. Disc sensitivity testing.
99.9% of the bacteria.

In serious infective processes which do not respond favourably to the usual effective agents there is a need for rapid determination of an effective drug. Folsam et al. (1960) evaluated a 12 hour disc sensitivity test which was both dependable and accurate. In addition to determining which of the drugs was most effective, equally important information was obtained in regard to which drugs were not effective. This sort of negative information is also of great clinical value, as the use of an ineffective agent entails the serious risk of sensitising the patient to a drug which might otherwise be life-saving at some future date.

Determination of bacterial beta-lactamase activity

Some isolates of *Staphylococcus aureus*, *Haemophilus influenzae* and other bacteria are resistant to penicillin or ampicillin or both because they produce a beta-lactamase that inactivates this antimicrobial agent. Rapid methods for detection of beta-lactamase allow testing as soon as colonies are isolated, very often 12 to 24 hours before susceptibility results are available.

Serum Bactericidal Activity

Serum sampling can be synchronised to coincide with anticipated peak and trough levels of antimicrobial activity. The assay provides an indirect measure of the susceptibility of the test organism and of the serum concentration of the antimicrobial agent. This method has been used for many years to guide the treatment of bacterial endocarditis.

Assay of Antimicrobial Activity in Serum

Accurate measurement of serum concentrations of antimicrobial agents may be necessary both to ensure adequacy of treatment and to prevent toxicity. These tests have been most useful in the case of agents which the margin between therapeutic and toxic levels is narrow, such as the aminoglycosides
or in patients with renal failure who may accumulate unusually high levels of antimicrobial agents that are normally excreted by the kidneys. A number of assay methods have been developed, in particular, for gentamycin because of its widespread use and association with renal and eighth nerve toxicity (Topazian and Goldberg; Rosenblatt 1977, Nolte).

4.1.6 Conclusion

The treatment of infection is usually initiated prior to obtaining laboratory reports for sensitivity of the microorganisms to antibiotics. Institutional profiles of the distribution of organisms by body site and antimicrobial susceptibility are generally available so that empirical therapy can be commenced. Proper preparation of the site and careful specimen collection and transport techniques are essential so that useful information is then available from the laboratory.

Isolation of bacteria in the laboratory depends on the use of selective and differential culture media incubated under both aerobic and anaerobic conditions. Identification is based on gross and microscopic colony morphology and biochemical and serological reactions. In vitro antimicrobial susceptibility testing is then carried out. The minimum inhibitory concentration of an antimicrobial agent may be determined and correlated with levels, achievable by various doses and routes of administration and necessary to ensure effective therapy.

4.2 The Role of Computerised Tomography (C.T.) in the Diagnosis of Orofacial Infections

Computerised tomography (C.T.) has revolutionised the art of diagnosis by non-invasive techniques. It produces a two-dimensional image produced from a series of algorithmic calculations derived by measuring X-ray attenuation of a finite set of projections of the three-dimensional object. C.T. offers several advantages compared with conventional radiographs:
First, there is no superimposition of image, as each tomogram represents a cross-section through an area examined.

Second, details of soft tissue are preserved. The soft tissues can be evaluated and the difference between specific tissue densities such as blood, tumour or calcified tissue recognised.

Third, because the image that is produced is formulated by a computer, areas of interest may be selectively viewed and enlarged.

Fourth, axial, coronal and sagittal tomograms can be obtained allowing the clinician to view the region three dimensionally.

Fifth, there is the capability of expansion with the advancement of computer technology.

A significant disadvantage of C.T. is the artifact produced by metallic dental restorations. Scans of the alveolar ridges and dentition are therefore of little value in patients with extensive restorations (Ames 1980).

Orofacial infections can extend into many areas that are normally difficult to evaluate with conventional radiography. Intracranial extension of an infective process originating in the maxillofacial complex may be seen in its early phase with C.T. Spread of infection within the orbit can produce retrobulbar swelling and this can be assessed well with C.T. scanning (North et al 1981). C.T. can be used to demonstrate whether a patient has only cellulitis of the neck tissues or whether the space in question has an abscess displacing the adjacent soft tissue structures. It is, therefore, helpful in evaluation of trismus when infection is suspected and in differentiating which space has an abscess or whether more than one space is involved. Involvement of more than one space may occur resulting in inadequate drainage if the surgeon is unaware of the extent of involvement. C.T. demonstrates the extent of airway obstruction but is academic, because
the diagnosis is clinically obvious (Murphy 1985, Endicott 1982).

The appearance of a deep-neck abscess on C.T. is demonstrated by:

- single cystic or multi-loculated appearance
- low density C.T. number
- air and/or fluid at the centre of the abscess
- contrast enhancement of the abscess wall
- tissue oedema surrounding the abscess wall
- anatomical boundaries that fit fascial spaces

Patients with dental infections that extend into the parapharyngeal spaces are often difficult to evaluate clinically, due to the severe trismus that makes examination of the oral cavity and oropharynx difficult. C.T. with soft tissue enhancement is valuable in assessing the displacement of parapharyngeal soft tissues and the secondary impairment of the airway that the soft tissue displacement creates. Areas of localisation of pus can also be identified.

Infections involving the major salivary glands can be evaluated by conventional sialography though in some circumstances the salivary ducts can be difficult to cannulate. C.T. can be helpful in distinguishing infiltrating neoplastic masses from salivary gland enlargement secondary to sialadenitis. C.T. will also evaluate maxillary, ethmoidal, sphenoidal and frontal sinuses easily.

Holt et al (1982) reviewed 22 patients, all of whom underwent scanning of the head and neck region when there was a suspicion of a deep neck abscess in the differential diagnosis. Six patients had positive findings on C.T. scan highly suggestive of a deep neck abscess, and underwent surgery when the radiographic diagnosis was clinically confirmed. There was excellent correlation of the level of the index of suspicion with the presence of a deep neck abscess, and C.T. effectively answered the question of abscess
versus no abscess. Endicott (1982), Murphy (1985) and Hall (1985) reported how C.T. scanning aided in the diagnosis and surgical management of patients with orofacial infections of the head and neck. In particular, the findings from these patients demonstrate the usefulness of C.T. in the diagnosis of abscesses which are deep to anatomical structures and have no superficial fluctuance.

Hardin et al (1985) retrospectively reviewed 32 patients with masticator space disease, half with infections and half with tumours. They considered that C.T. examination provided significant new data in 14 of the 16 patients with orofacial infections. The data indicated the presence or absence of fluid collections, the presence of bony irregularities suggesting osteomyelitis, or the involvement of neck spaces other than those clinically suspected. The C.T. scans showed that seven patients had infections confined to the masticator space, while eight patients had complex, deep facial infections originating from the masticator space. Spread of infection downward into the spaces of the neck and floor of the mouth was demonstrated in five of these patients and infection spreading upward to the base of the skull and temporal spaces was shown in three of these patients. Traditionally, the patient with a masticator space infection is described as having facial swelling, pain and trismus and usually requires extra-oral drainage to drain the space and to explore adjacent deep spaces. It is usually assumed that when the masticator space infection breaks out of the fascial boundaries the infection spreads upward into the temporal space and the base of the skull. However, this study showed that half of these patients had infection which spread downward into the neck and floor of the mouth. Therefore, following evaluation of the C.T. scans appropriate surgical procedures were implemented.

The authors concluded that in masticator space infections C.T. enables
differentiation of inflammatory change from focal pus collections; identification of osteomyelitis of the mandible or maxilla; and differentiation of clinically occult adjacent space infection from infection confined to the masticator space thereby helping to direct surgical drainage.

Nyberg et al (1985) also found that C.T. was valuable in examining cervical infections, particularly for localising abscesses in widespread and complex infections. They presented their work with 31 patients and reported that in each patient C.T. detected and localised an abscess that guided subsequent surgical drainage, which was followed by prompt clinical improvement.

It would appear that C.T. is a valuable method for evaluating orofacial and cervical infections that are difficult to assess clinically.

4.3 Ultrasonography in the Preoperative Evaluation of Neck Abscesses

Diagnostic ultrasonography has been used widely in the evaluation of thyroid lesions but rarely for the study of extra-thyroidal neck lesions. Kreutzer et al (1982) evaluated 40 patients with probable neck abscesses with ultrasonography to determine the necessity and timing of surgical drainage, and to correlate the results with the physical and operative findings. The data recorded from the ultrasonography of the neck included:

1. the location of the inflammatory mass and the location of cystic components (if present) within the mass
2. the general sonic nature of the mass
3. the approximate volume of fluid within any cystic component of the mass
4. pertinent structures within the mass

Most investigators feel that the specific strengths of ultrasonography in studying inflammatory cervical masses are the demonstration of fluid (pus) within the mass, and the identification of structures adjacent to the abscess.
In this study of 40 patients the findings of physical examination were inadequate in the prediction of pus within an inflammatory neck mass, as only 8 of 24 proven abscesses were thought to be fluctuant pre-operatively. However, ultrasonography was 95% accurate in predicting purulent material and in only one patient did ultrasound fail to demonstrate pus in the abscess cavity. In five patients the results of pre-operative ultrasonography guided surgical exploration for secondary, deeper abscess cavities that were unidentifiable after drainage of the more superficial abscess.

A number of points in the interpretation of ultrasonographic neck scans are:

First, the entire neck should be evaluated instead of just the palpable abnormality. This is because demonstrable abnormalities are often more extensive than the superficial abnormality.

Second, the abnormal mass should be classified as cystic, complex or solid in nature. Most abscesses appear as complex masses with irregular cystic centres or as solid masses with low echogenic centres. Both situations suggest the presence of pus or necrotic debris. Cellulitis or muscle inflammation appears as homogenous echogenic solid masses.

Third, is the problem that a truly cystic lesion may appear solid by ultrasound criteria. This is usually caused by atypical fluid within the cyst.

The authors concluded that diagnostic ultrasound was an inexpensive, non-invasive and sensitive means of confirming a diagnosis of neck abscess.

4.4 Closed Percutaneous Catheter Drainage of Abscesses of the Head and Neck

Incision and drainage is the standard treatment for head and neck abscesses, usually with the placement of drains, either intra-orally or extra-orally to aid in evacuating the pus. This procedure requires an open surgical intervention for placement. Needle aspiration or percutaneous
drainage has been used not only as a diagnostic technique but also as the
sole surgical modality in the treatment of peritonsillar abscesses. Herzon
noted that over 90% of the 115 peritonsillar abscesses reported in the
literature resolved completely with needle aspiration alone. It was,
therefore, suggested that this technique could also be used for non-tonsillar
abscesses of the head and neck region. There are several advantages to this
technique:
- It can be used with local anaesthetic and computed tomographic
guidance.
- C.T. imaging can provide a broader field of view with good determination
of the lesion as opposed to the limited view through a surgical incision.
- The exact cutaneous entry site and proposed catheter route can be
meticulously planned based on size, location and anatomic relationship of
the abscess to the surrounding structures.
- Percutaneous catheters are easily retained allowing aspiration, irrigation
and either gravity or suction drainage.
- The percutaneously placed drain also allows pus to be collected distantly,
keeping the skin dry. This diminishes irritation, excoriation, and
possible potentiation of infection.
- Aesthetically pleasing post-operative results are possible with minimal
scarring (Sacks 1985).

Herzon (1985) reported on ten patients with abscesses of the head and
neck region; of which eight resolved completely with needle aspiration plus
antibiotics, though four required multiple aspirations. The other two
patients in the study required formal surgical incision and drainage. The
author concluded that a non-peritonsillar abscess of the head and neck region
which appears to be well localised and has neither a large cellulitic
component nor an associated severe systemic reaction may be managed by one
or more needle aspirations as the sole surgical modality.

Cole et al (1984) described the percutaneous catheter drainage of deep neck infections guided by CT in two patients. The authors concluded that the basic principles of percutaneous drainage apply to the neck. The distance to the near and far wall of the abscess cavity is recorded and it should be recognised that the superficial skin is being pushed in during puncture. The inner stylet is periodically removed for aspiration and only a tiny amount of pus is removed until the catheter is in place. Then the abscess cavity is fully aspirated and a specimen is sent for Gram stain and aerobic and anaerobic culture and sensitivity testing. Periodic aspiration can then be performed. It was thought that percutaneous drainage under certain circumstances, using local anaesthesia, had the potential benefit of a non-operating room procedure and gave excellent cosmetic results.

4.5 Conclusion

The place of diagnostic techniques including microbiological identification and sensitivities and the role of CT scanning, ultrasonography and percutaneous catheter drainage in the management of orofacial infections has been discussed.
CHAPTER 5

ANTIMICROBIAL AGENTS
5.1 Pre-antibiotic Era

5.1.1 Zinc Peroxide

Before the advent of antibiotics the use of local antimicrobial agents such as zinc peroxide, were of importance. It was thought that zinc peroxide was first made in 1810 by Thenard but its use as an antiseptic was suggested by Elias in 1903, and, thereafter, favourable results were reported with its use in the treatment of several dermatological diseases by Hartung (1904), Mayer (1907), and Paucot (1905). Hochstetter (1905) reported an unusual case of gangrenous ulcer of the face which responded favourably to the use of zinc peroxide. Chaput (1904) thought that zinc peroxide met every requirement of an antiseptic, because it was non-toxic, non-caustic, non-irritating and could be sterilised without affecting its antiseptic value. He attributed its clinical action to the slow liberation of oxygen over a period of hours. Vanverst (1904) confirmed the observations made by Chaput. Laurent, who studied zinc peroxide for his doctor's thesis at the University of Paris, believed that it detoxified the poisonous products of bacteria and favoured the migration of leucocytes and their phagocytic action on the organisms.

These authors employed zinc peroxide in the form of powder, ointment, or lotion and all were impressed by the deodorant action and the stimulation of wound healing. However, they did not study the bacterial flora of the wounds which they were treating, nor attempt to work out a strategy for the selection of cases for this treatment. Perhaps, it was for these reasons that zinc peroxide was not more widely used. It seems to have fallen into disrepute as nothing is found in the medical literature about it in the years 1910 to 1926. The next mention of it was by La Ferla (1927) and Pignateria (1927) who independently reported the successful treatment of trachoma with zinc peroxide.

In 1935 Meleney observed that the use of zinc peroxide on chronic,
non-gangrenous lesions of the abdominal wall produced healing by granulation and without irritation of the tissues. In vitro testing also confirmed that zinc peroxide would inhibit the growth of micro-aerophilic and anaerobic organisms. Therefore, its use was more extensively advised.

Meleney et al (1937) reported that the more strict the organism is in its anaerobic requirements, the more susceptible it is to zinc peroxide. The authors advocated that the active treatment of surgical infections with zinc peroxide should await the bacteriological identification of the wound flora and should only be used if the organisms were susceptible to peroxides. Meleney's experiments indicated that the liberation of hydrogen peroxide depended upon the presence of water and found that zinc peroxide was much more bactericidal in a water suspension than in oil. In 1938 Meleney presented a paper to the New York Surgical Society emphasising the use of zinc peroxide in "foul smelling mouth and neck infections". He thought that zinc peroxide was a most effective oxidising agent in the treatment of mild infections of the mucous membrane. Although surgery was required when infection had spread to much deeper layers the exposed tissues could be treated with zinc peroxide. Meleney advised that external zinc peroxide dressings should be changed every 24 hours and that zinc peroxide mouthwashes should be used every 3 to 4 hours. He also advocated the use of zinc peroxide as a prophylactic mouthwash prior to dental extractions or to tonsillectomy.

Mallett and Guralnick (1942) were guided by Meleney's work and used zinc peroxide in many patients with severe Vincent's stomatitis, cellulitis with foul smelling extractions and pericoronal flap infections with good results. They pointed out that the action of the zinc peroxide was not curative but could resolve a painful foul infection to the point of comfort and improve appearance in 2 to 3 days. The authors concluded by advocating the use of
zinc peroxide because of its chemical action, its inability to damage mouth
tissues and its ease of application.

5.1.2 Irradiation

In the first three decades of the 20th century radiotherapy was used in
the treatment of many acute, subacute and chronic inflammatory conditions. The possible value of radiotherapy in inflammatory conditions resulted from
the observation of unexpected benefit following exposure for diagnostic
purposes of parts of the body which were the seat of inflammatory lesions.
The theories of action of the X-rays were naturally numerous but it was
Heineke's work from 1903-1905 which showed the exceptional sensitivity of
lymphocytes to roentgen rays and radium.

The success of irradiation on a vast number of pyogenic infections was
reported by many authors. Infections were treated early in lesion formation
when leukocytic infiltration was maximal. It was thought that the subsequent
course of the infection would be altered and would probably not reach
suppuration. The dose of radiation was very small; if the dose necessary to
cause erythema of the skin was taken as 100%, then the dose for acute and
subacute inflammations was generally less than 50% and sometimes as little
as 25%. Such a dose did not cause any reaction by the normal skin or the
system as a whole, nor did it produce the side effects of anorexia, vomiting
and nausea which often follow exposure to maximum doses. Irradiation was
used in treating many patients with 'inflammation of the dental periosteum'
as reported by Pordes (1926). It was used in the treatment of other orofacial
infections and was particularly recommended to prevent the spread of
cellulitis towards the dangerous region of the angular vein (Galloway 1937).
In a review of published reports, Desjardins (1931) showed that the majority
of patients derived great and prompt benefit from irradiation. It was
concluded that irradiation in small dosage for combating infections was safe
and could be of considerable value when properly used.

5.1.3 Neo-arsphenamine

Because bacteriological studies had proved that Borrelia vincenti was an offending organism in cervical infections secondary to diseases of the mouth, Alden (1936) and Boyne (1938) administered neo-arsphenamine with much success. They stated that in some patients the inflammatory mass subsided entirely without further treatment and therefore avoided the necessity for external drainage of an infection. Alden advocated the practice of giving neo-arsphenamine in the treatment of all types of cervical infections and prior to the removal of infected teeth, whether or not Borrelia vincenti was be identified.

5.2 Antibiotic Era

The advent of antibiotics for the practical therapy of infectious diseases began in 1929 with the observation by Alexander Fleming, that Staphylococci growing on a plate culture were inhibited by a chance contamination with a penicillium species. This mould produced an antibiotic which Fleming called penicillin. After much investigation penicillin was isolated by Chain and Florey as an impure brown powder and by 1941 its therapeutic efficacy was well established. After 1941, an extensive systematic search was begun for moulds and bacteria that might produce other antibiotics. Innumerable lives have been saved and dentistry particularly has benefited from the discovery of penicillin, because most odontogenic infections are caused by penicillin-sensitive microorganisms.

However, it soon became evident that antibiotic usage was accompanied by some considerable risks. Allergy to penicillin occurred and a variety of toxic and idiosyncratic reactions emerged ranging from simple nausea to fatal aplastic anaemia. Superinfection by normally nonpathogenic bacteria also resulted from the change in microbial flora. Finally, there was the
development of antibiotic resistance. Despite the disadvantages, the treatment of patients with antibiotics was usually the first option: "Give antibiotics to cure an infection" (Jackson 1974).

5.2.1 Selection of an Antibiotic

Once the decision has been made to use antibiotics as an adjunct to treating an infection, the antibiotic should be carefully selected. The following guidelines are useful in making this decision:

- identification of the causative organism,
- determination of the antibiotic sensitivity,
- use of a specific narrow-spectrum antibiotic:
- use of the least toxic antibiotic,
- patient's drug history,
- use of a bactericidal rather than a bacteriostatic drug,
- use of an antibiotic with a proven history of success,

5.2.2 Principles of antibiotic administration

The administration of an antibiotic involves consideration of dosage, route of administration and combination therapy. The aim is to administer a sufficient antibiotic dose to achieve the desired therapeutic effect without causing injury to the host. The laboratory assists the clinician in calculating the correct dosage by determining the minimum inhibitory concentration (MIC) of an antibiotic for a specific bacterium. MIC values for commonly used antibiotics against the most common bacteria have been established, and for therapeutic purposes the optimal concentration of antibiotic at the site of infection should be 3 to 4 times the MIC. Therefore, the dosage prescribed must be capable of attaining a concentration of antibiotic that is 3 to 4 times the MIC. In general, therapeutic levels
higher than 3 to 4 times the MIC do not improve the therapeutic results though in situations where the site of infection is isolated from the blood supply increased levels may be justified. However, it should not be forgotten that toxic levels of antibiotics may be critical. Knowledge of the pharmacokinetics of the drugs is necessary to establish the frequency of dose administration. Each antibiotic has an established half-life ($T_\text{h}$) in plasma. The usual dosage interval for the therapeutic use of antibiotics is four times the $T_\text{h}$. Since most antibiotics are eliminated via the kidneys the patient with pre-existing renal disease may require longer intervals between doses (Hewitt 1978).

The route of administration may be oral, intramuscular or intravenous depending on the necessary serum levels required. The oral route results in the most variable absorption and most antibiotics are taken in the fasted state to achieve maximum absorption. When treating a serious infection parenteral antibiotic therapy is frequently the method of choice and it is important to maintain peak levels of antibiotic in the blood for an adequate period of time to obtain maximum tissue penetration and effective bacterial killing. Bacteria are not usually eradicated until the antibiotic has been administered for 5 to 6 days.

There are a few situations in which the use of multiple antibiotics are considered necessary; first, with life-threatening sepsis of unknown cause when it is necessary to increase the antibacterial spectrum; secondly, when it is important to increase the bactericidal effect against a specific organism, and thirdly, when combined therapy prevents the emergence of resistant bacteria, as in the treatment of tuberculosis (Lang 1984, Jawetzl 1968).

5.2.3 Response to Antibiotic Therapy

In the management of patients with orofacial infections there will
rarely be a noticeable response to antibiotic therapy for the first 24 to 48 hours unless surgery to accomplish drainage is also performed. Usually some response is expected by the second day in a subjective sense of just "feeling better", but from then onward objective signs of improvement will occur including a decrease in temperature, swelling and pain and a lessening of trismus in relation to oral infections. The duration of the course of antibiotics is governed by the patient’s improvement though a course of less than 5 to 7 days is rarely advisable.

Occasionally, a patient will respond to therapy even though culture and sensitivity testing indicates that the bacteria present are resistant to the antibiotic being used empirically. In this situation, the combination of surgical and antibiotic treatment and the natural host defenses has resulted in resolution of the infection. It should not be forgotten that in vivo activity is not always the same as in vitro activity, and therefore no change should be made where the antibiotic is clinically successful. Conversely, empirical therapy may not have resulted in resolution, even though the culture and sensitivity reports support the choice of the empiric antibiotic. Other factors must be considered including the severity and location of the infection as well as the dose and route of administration of the antibiotic and the virulence of the bacteria involved.

5.2.4 Choice of Antibiotics in Orofacial Infections

The use of antibiotics is a very important adjunct to the treatment of orofacial infections. Once adequate surgical management has been undertaken and bacteriological studies indicate the aetiological agents then the question can be asked 'Which antibiotic is most effective in the greatest number of orofacial infections?' Surveys of groups of individuals with dental infection are constantly being carried out, so that the changing bacteriology and antibiotic sensitivities can be available to the clinician
involved in their management.

Herrell et al (1942) confirmed the antibacterial activity of penicillin and reported on the use of penicillin in a patient with severe facial and orbital cellulitis due to infection by Staphylococcus aureus. The patient showed a dramatic improvement within 24 hours of penicillin therapy. Other reports showing the efficacy of penicillin in orofacial infections soon appeared (Herrell 1943 and 1944; Dorner 1945; Bean 1945, Northrop 1949). Penicillins remain as effective against many bacteria nowadays as when they were first introduced but the emergence of penicillinase-producing Staphylococci has made the original penicillins ineffective against infections caused by such organisms. However, new semi-synthetic penicillins have been produced which have a wide range of activity.

Sims (1974) noted that tetracycline was the first antibiotic to become available which could be given by mouth and was therefore popular with dental surgeons. However, increasing numbers of strains of Streptococci had become resistant to tetracycline, so that it was no longer recommended as the drug of choice. Sims stated that penicillin had become the antibiotic of choice with erythromycin the best alternative.

Gabrielson and Stroh (1975) studied the efficacy of 13 antibiotics in the management of 84 patients with odontogenic infections. The five most frequently isolated organisms were determined by bacteriological examination and 99% of the patients had at least one or more of these organisms. The antibiotic data for these five organisms was collected and tabulated, and this indicated the percent sensitivity of a given organism to a given antibiotic. With this information the antibiotic efficacy could then be established. The results of this investigation showed chloramphenicol to be 100% effective and was therefore used as the reference standard. Erythromycin was found to be 99% effective and penicillin 91% effective.
Even though chloramphenicol was a 100% effective it was not considered the drug of choice, except in very rare life-threatening situations because of its associated severe toxic side effects. Penicillin was formerly the drug of choice but with its widespread use over the years bacterial resistance had become a significant problem. As a result, the clinical efficacy of penicillin has decreased. In this study erythromycin was considered the drug of choice as it had one of the highest degrees of efficacy together with low degrees of adverse systemic manifestations.

Olsen (1975) found that clindamycin should not be used if penicillin or erythromycin were acceptable because there had been several deaths and numerous reports of clindamycin-associated Pseudomembranous colitis. As the oral anaerobic organisms causing orofacial infections are sensitive to penicillin, clindamycin should be reserved for those cases where it is the preferred drug, namely anaerobic penicillin-resistant infections. Schuen (1974) had compared the use of penicillin and clindamycin in orofacial infections and concluded that the response to these drugs was essentially the same. Mehrhof (1976) evaluated the role of clindamycin in dental treatment and concluded that clindamycin should only be used in proven cases of Bacteroides fragilis infection and that close attention should be given to the possible development of gastrointestinal complications. Mehrhof considered that clindamycin is not a first-line drug in the management of orofacial infections.

Epstein and Scoop (1977) examined 13 patients with periapical and periodontal abscesses. The most common organism cultured was Streptococcus viridans and the antibiotic sensitivities indicated that penicillin was the most effective of the antibiotics besides chloramphenicol. Tetracycline was found to be the least effective, similar to Gabrielson's findings. Erythromycin was the next most effective drug and was considered the
alternative when the patient was allergic to penicillin.

Penicillin has always been the drug of choice for the treatment of acute odontogenic infections based on the fact that many of the organisms cultured from the oral cavity were sensitive to this drug, including both aerobic gram positive bacteria and anaerobes. Continued studies on the bacteriology of dental infections has suggested that the anaerobes might be the more important pathogens; this hypothesis had been difficult to investigate because of the lack of an agent with anti-bacterial activity restricted to anaerobic organisms. However, the drug, metronidazole fulfilled this requirement. Therefore, Ingham et al (1977) performed a blind controlled study comparing metronidazole with penicillin in the treatment of acute dental infections. The trial included 37 patients in whom a marked clinical improvement was apparent within 24 to 48 hours of antibiotic therapy. Based on these observations it was suggested that metronidazole appeared to be as effective as penicillin. The conclusion drawn was that since metronidazole was only effective against obligate anaerobes, these organisms must be regarded as of particular importance in such infections. It was also noted that in this trial obligate anaerobes accounted for 72% of the total bacterial isolates. Hood (1978) successfully treated a further 100 patients with acute dental infections with metronidazole and regarded metronidazole as a very satisfactory alternative drug to penicillin.

McGowan et al (1977) carried out a double blind trial on 43 patients comparing metronidazole to penicillin in the treatment of acute pericoronitis. Analysis of the data suggested that the two drugs were equally effective in reducing the signs and symptoms of severe acute pericoronitis. However, it was thought that penicillin may have had the more beneficial effect on decreasing the frequency of palpable lymph nodes.

Hunt et al (1978) studied the incidence of bacterial resistance to the
antibiotics routinely used to treat oral infections. They found that 68 exudates produced growth on culture, of which 56 were pure cultures and 12 mixed cultures. Streptococci and Staphylococci accounted for 57% and 34% respectively of the pure cultures. Anaerobic bacteria were found in nearly 15% of the pure culture exudates. This investigation and earlier studies showed that the frequency of infections caused by anaerobic organisms was increasing and that most of the isolates in this investigation were still susceptible to a spectrum of currently available antibiotics.

Dornbusch (1980) considered that penicillin remained the drug of choice for oral bacteria but that in patients with an allergy to penicillin, erythromycin, clindamycin, doxycycline or metronidazole could be recommended. Other authors who considered penicillin the drug of choice included Dirlam (1980), Woods (1978), Hills-Smith (1983), Heimdahl (1985) and Schliersen (1986). Patterson (1980), in his update on Ludwig's Angina, also recommended penicillin given intravenously in very high dosages (12 to 20 million units daily) until Gram stains and culture results indicated otherwise.

von Konow et al (1983) carried out a double blind study on 60 patients to compare the efficacies of penicillin and ornidazole in the treatment of orofacial infections. Ornidazole belongs to the same group of drugs (Nitroimidazoles) as metronidazole, having the same antibacterial spectrum but a longer half-life. The clinical outcome showed that all the patients in the ornidazole group and 25 of the 30 patients in the penicillin group were cured within 7 days. The other 5 patients in the penicillin group responded satisfactorily to supplemental antibiotics, 3 with metronidazole and 2 with clindamycin. Bacteriological findings for 3 of the latter patients indicated the presence of penicillin-resistant Bacteroides strains. The remaining 2 patients were successfully managed with metronidazole because nitroimidazoles have a higher ability than penicillin to penetrate oral
biological barriers therefore giving higher concentrations at the site of infection than penicillin and thus being more effective. The bacteriological results in this study found no Staphylococci but isolated anaerobic bacteria from all specimens with 65% of the specimens growing only anaerobes. It was concluded that since ornidazole was an effective antimicrobial agent in all instances, this would indicate that obligate anaerobes were the most important pathogens in orofacial infections. In vitro studies comparing the susceptibilities of anaerobic bacteria to metronidazole, ornidazole and new agents of the nitrimidazole group have been carried out and all these agents show marked activity against virtually all anaerobes tested and therefore may prove invaluable in the treatment of anaerobic infections (Goldstein 1978). Other studies (Hood 1978; Stavrou et al 1987) have shown effective levels of metronidazole are achieved within the bone of the mandible.

Cumming et al (1984) assessed the efficacy of a new semisynthetic cephalosporin, cefadroxil, in the management of orofacial infections of 20 patients. This antibiotic had been shown to have a wide spectrum of activity against both aerobic and anaerobic bacteria which could be of importance in the treatment of orofacial infections. Cefadroxil was also bactericidal to beta-lactamase-producing bacteria. On the basis of the successful results in this clinical trial it was suggested that this new drug should be included in the list of alternative drugs that could be used in the management of facial infections.

5.2.5 Conclusion

The place of antibiotic therapy in the management of orofacial infections has been correctly summarised by Heimdahl (1985) who stated that antimicrobial treatment is of secondary importance to surgical incision and drainage but is indicated when the patient’s general condition is influenced by the infection. He concluded that penicillin is still the drug of choice
but due to the increasing number of beta-lactamase producing anaerobes, metronidazole is also recommended.