Endoscopic treatment in OCMFS

Ioakeim Kyriakos[1], Nicolaou Zoe[2]

[1]Rambam Hospital, Haifa, [2]Cyprus Cranio Maxillo Facial Center

Ενδοσκοπική θεραπεία στη Στοματική & Κρανιο-Γνάθο-Προσωπική Χειρουργική

Ιωακείμ Κυριάκος[1], Νικολάου Ζωή[2]

[1]Rambam Hospital, Haifa, [2]Cyprus Cranio Maxillo Facial Center

DOI: 10.54936/haoms23287109

Literature Review
Βιβλιογραφική Ανασκόπηση

SUMMARY: The Oral & Cranio-Maxillo-Facial Surgery (OCMFS) specialty has entered a new era with the use of endoscopic techniques. Surgeons can now use the latest technological advances in order to improve patient outcomes.
The application of endoscopic surgical techniques in OCMFS not only has decreased the morbidity associated with surgical approaches, but it has significantly changed the treatment philosophy for many types of procedures.
Temporomandibular Joint (TMJ) arthroscopy, Sialoendoscopy, Trauma cases such as frontal sinus fractures and orbital floor fractures and subcondylar mandible fractures are the most notable examples where endoscopic techniques have found worldwide acceptance.
Additional research has to be done in order to simplify some difficult techniques that often require more extensive surgical exposure for better visualization.
Although minimally invasive endoscopic techniques are also used in facial cosmetic surgery, the discussion in this literature review article focuses on non-cosmetic procedures and mainly on TMJ arthroscopy, Sialoendoscopy and Facial Trauma.

KEY WORDS: *maxillofacial surgery, endoscopy, arthroscopy, sialendscopy, fractures, trans-antral approach, transnasal approach*

ΠΕΡΙΛΗΨΗ: Η ειδικότητα της Στοματικής & Κρανιο-Γναθο-Προσωπικής Χειρουργικής (OCMFS) έχει εισέλθει σε μια νέα εποχή με τη χρήση ενδοσκοπικών τεχνικών. Οι χειρουργοί μπορούν πλέον να χρησιμοποιούν τις πιο πρόσφατες τεχνολογικές εξελίξεις προκειμένου να βελτιώσουν τα αποτελέσματα στους ασθενείς τους.
Η εφαρμογή ενδοσκοπικών χειρουργικών τεχνικών στη OCMFS όχι μόνο έχει μειώσει τη νοσηρότητα που σχετίζεται με τις χειρουργικές προσπελάσεις, αλλά έχει αλλάξει σημαντικά τη φιλοσοφία της θεραπείας για πολλούς τύπους επεμβάσεων.
Η αρθροσκόπηση της κροταφογναθικής άρθρωσης (TMJ), η Σιαλοενδοσκόπηση, οι περιπτώσεις τραύματος όπως σε κατάγματα μετωπιαίου κόλπου, σε κατάγματα εδάφους του οφθαλμικού κόγχου και σε υποκονδυλικά κατάγματα κάτω γνάθου είναι τα πιο αξιοσημείωτα παραδείγματα όπου οι ενδοσκοπικές τεχνικές έχουν βρει παγκόσμια αποδοχή.
Πρέπει να γίνει πρόσθετη έρευνα προκειμένου να απλοποιηθούν ορισμένες δύσκολες τεχνικές που συχνά απαιτούν πιο εκτεταμένη χειρουργική προσπέλαση για καλύτερη ορατότητα.
Αν και οι ελάχιστα επεμβατικές ενδοσκοπικές τεχνικές χρησιμοποιούνται επίσης στην αισθητική χειρουργική προσώπου, η συζήτηση σε αυτό το άρθρο ανασκόπησης βιβλιογραφίας επικεντρώνεται σε μη αισθητικές επεμβάσεις και κυρίως στην αρθροσκόπηση της TMJ, τη Σιαλοενδοσκόπηση και το Τραύμα Προσώπου.

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ: *γναθοπροσωπική χειρουργική, ενδοσκόπηση, αρθροσκόπηση, σιαλενδοσκόπηση, κατάγματα, δια-ρινική προσέγγιση*

[1] DDS, MD, OCMFS resident physician
[2] Oral & Maxillofacial Surgeon

Paper received: 8/3/2022 - Accepted: 29/8/2022

Παρελήφθη: 8/3/2022 - Έγινε δεκτή: 29/8/2022

Minimally Invasive Surgery (MIS) Chronology - from Hippocrates to the 21st Century.

Endoscopy began in the 4th Century BC, when Hippocrates used a speculum to examine the rectum of a patient (1). Moreover, written descriptions of gynecologic speculums were discovered in the Babylonian Talmud (2).

Arthroscopy began in 1918 by Tagaki for examining the knee joint, but it is only in the last 40 years that it has been broadly used in the maxillofacial region (3, 4). Dr. Onishi was the first one who reported TMJ arthroscopy in 1970 and his first results were published in 1975 and 1980.

The digital video camera was introduced in 1982 (5) and gave the ability of live surgical viewing, through a screen, during endoscopic procedures.

Technological advancements led to different types of endoscopes and new instrumentations resulting in improvements in oral & maxillofacial surgery procedures. MIS produces fewer complications, with a reduced risk of death and morbidity. Other advantages of MIS, but also disadvantages are presented in Table 1.

There is a wide extent of application of endoscopic techniques in OCMFS (Table 2) and it is now approaching deeper parts in some specific fields. In other fields it is still under research and investigation and as science and technology advance at a rapid pace, in the near future we will have greater intervention possibilities, with the sole aim of offering high quality treatment to patients.

ARTHROSCOPY OF TMJ

Introduction

TMJ arthroscopy serves as a diagnostic and therapeutic tool. As we mentioned above, the first report of TMJ arthroscopy was published by Prof. M. Ohnishi in 1970 (10). However, TMJ arthroscopy became popular by Dr. Ken Ichiro Murakami in 1981, 1982, and 1985 (11, 12, 13). It is worth mentioning that the first published reports in the American literature were by Dr. McCain in a meeting for AAOMS in 1985 and Drs. Nuelle, Alpern, and Ufema in 1986 (14,15,16). A comprehensive study was also published by Dr. Bruce Sanders in 1986 (17).

As in any operative procedure, similarly in TMJ arthroscopy there are indications and contraindications. Most of them are mentioned below:

Indications for TMJ arthroscopy

- Pain and jaw dysfunction due to TMJ internal derangement not responsive to conservative treatment (21)
- Radiographically, TMJ bone structure changes, typical to Osteoarthritis (OA) with disc displacement or distortion and failure of conservative treatment with NSAIDs, intraoral splints and/or arthrocentesis (22,23)
- Involvement of the TMJ in patients with a background medical history of rheumatoid arthritis, juvenile idiopathic arthritis, Still's disease or any other connective tissue diseases (in these cases a biopsy should also be performed) (24)
- Inflammatory/septic arthritis (21)
- Hypomobility (closed lock) secondary to intrajoint adhesions (21)
- Persistent preauricular atypical facial pain
- Management of hypermobility resulting in painful recurrent subluxation or dislocation (21, 25)
- Post-traumatic complaints may also be an indication for TMJ arthroscopy (22,23)
- Wilkes's classification stages III, IV and V (26)

Contraindications for TMJ arthroscopy (22, 23)

- Some TMJ diagnoses (e.g. tumors, ankylosis, growth abnormalities) exhibit indications for TMJ open surgery
- Cases of acute arthritis. In these conditions, because of the presence of large medial osteophytes on the condyle, large central cartilaginous perforations and fibrous/fibro-osseous/osseous ankylosis, it is better to handle them via open TMJ surgery
- An undiagnosed swelling of the jaw
- Chronic facial pain (types: neurogenic, muscular, psychological) such as temporal arteritis and trigeminal neuralgia
- Orthopedic diseases which present with limited neck mobility (relative contraindication)
- Overlying skin infections (can cause postoperative septic joint)

In TMJ arthroscopy, the goal is to treat the underline TMJ pathology and offer daily function stability to the patient. In order to achieve this, many operative procedures can be performed under the vision of the arthroscope. According to the McCain Classification, there are 3 different levels of TMJ arthroscopy (27):

Level I: This is a single-puncture arthroscopic technique, into the posterior area of the Superior Joint Space (SJS), along with the placement of an outflow needle. It allows for lysis and lavage (arthroscopic arthrocentesis) in addition to the diagnostic value of viewing the anatomy of the joint. Moreover, intra-articular medication can also be used during the procedure.

Level II: This is a double-puncture arthroscopic technique in which the arthroscopic cannula is inserted into the posterior area of the SJS and the operative cannula is inserted into the anterior recess of the joint and provides the possibility for performing procedures such as:

– Synovial biopsy (it assists in the identification of the underlying pathology)
– Lysis of adhesions (under direct vision)

Table 1: Advantages & Disadvantages of MIS (6, 7, 8, 9)

Advantages	Disadvantages
Minimal morbidity and mortality	May increase the cost of the treatment
Small surgical incision (no significant facial scar), less operative trauma, reduced incidence of neurovascular damage	Operative period is usually longer, especially when someone first attempts it
Bloodless procedure, increased flap/would stability allows stable primary closure of the wound	Requires intensive training (steep learning curve) and skills
Increased visibility especially in cavities difficult to access surgically	High cost of equipment and technical difficulties
Greater protection of important anatomical structures (vessels/nerves)	Optimal results require experience by the surgeon
Decreased postoperative complications (pain, bleeding, infection, edema, adhesions, scars)	
Quicker recovery and shorter hospitalization time	
Educational tool for trainees to become familiar with the surgical anatomy	

Table 2: Endoscopy applications in OCMFS

TMJ arthroscopy
Sialoendoscopy
Trauma (orbital floor fracture, mandibular angle fracture, subcondylar fracture, frontal sinus fracture)
Orthognathic surgery
Distraction osteogenesis procedures
Condylectomy, Coronoidectomy
Implantology
Jaw pathologies
Removal of foreign bodies in the maxillofacial region
Facial aesthetic surgery (forehead lift, brow lift, midface lift)

– Debridement of arthritic joints (for creating a larger joint space and smoother surfaces for improved function)
– Intra-articular holmium laser therapy
– Retrodiscal contracture (for reducing pleonastic synovium or treating recurrent mandibular dislocation from hypermobility)
– Targeted deposition of medication (e.g. PRP) via the operative cannula (disease modification)

Level III: Arthroscopic disc reduction and fixation (discopexy)

There are two types of TMJ arthroscopy (each one with a different technique):

- Diagnostic (single-puncture arthroscopy): Diagnostic and basic interventions
- Therapeutic (double-puncture or multiple punctures): The ability for advanced arthroscopic surgical procedures

In the following section of this article, both types of TMJ arthroscopy are presented with a brief step-by-step explanation and in a simple manner, so that the reader can apply these principles in his/hers daily work. There are of course many variations of techniques in the literature for specific operative maneuvers, but we decided to mention the simplest steps for performing a safe and effective TMJ arthroscopy.

Technique: Primary TMJ Arthroscopy

(Single-Puncture Arthroscopy) (27, 28, 29, 30, 31, 32, 33, 43)

Step 1: Patient Preparation

The primary TMJ arthroscopy procedure is performed under local anesthesia with or without Intravenous (IV) sedation or general anesthesia.

The patient is placed in the dorsal supine position and the patient's head is turned on one side so that it maintains a completely flat level. The hair is placed in a bouffant cap and it is secured with silk tape.

After digital localization of the greatest concavity of the glenoid fossa, the preauricular skin is prepared with Betadine, draped in the common way for TMJ arthroscopy and a sterile atraumatic ear wick is placed for protection.

Step 2: Local Anesthesia
After landmarks have been marked with a surgical pen, local anesthesia is injected using a 2% lidocaine solution with a 30-G needle in the preauricular area at the fossa portal lavage tract and the insufflation tract.

Step 3: Insufflation
The superior joint space is then insufflated (for the distension of SJS and also in order to avoid iatrogenic injury to the cartilaginous surfaces during the insertion of the trocar) via an inferior and lateral approach with the use of a 30-G needle and it is insufflated with a 1% lidocaine solution, approximately 2,5 ml (plunger rebound effect indicates the correct position).

Step 4: Fossa Portal Puncture
The first puncture is always placed at the maximum concavity of the glenoid fossa while the mandible is in protruded position (10 mm anterior from the middle of the tragus and 2 mm downwards on the canthotragal line).
The sharp trocar penetrates the tissue through a small skin incision, with a slow rotational motion (Figs. 1a and 1b). The fossa puncture should be made very carefully in an attempt to pass only one time through the lateral capsule and into the joint space, in order to avoid extravasation problems. Afterwards, the trocar is advanced until contact is felt with the bone above. Always use the bony landmark and never pass the instrument straight through the capsule without first locating the bone. Then, the sharp trocar is exchanged with a blunt trocar and the cannula is advanced completely into the joint space. At this point, the cannula should be inserted approximately 20 to 25 mm as measured from the skin to the center of the joint, which is well-known as the safety zone. At the end of this stage, the correct placement can be checked by infusing saline, at which point the fluid level in the canula will move simultaneously with the movement of the jaw. Finally, the trocar is removed and the athroscope is inserted.

Step 5: Insertion of the Outflow Needle
With the mandible maintained in a protrusive position, insufflate the joint with approximately 2 to 3 mL of fluid using the direct irrigation syringe and maintain pressure on the plunger in order to retain the distention of the joint. Then, insert a 22-G needle, approximately 20 mm anterior from the middle of the tragus and 10 mm inferior in the canthotragal line while observing the flow of the irrigation fluid through the needle consisting of lactated Ringer's solution with 1:300,000 epinephrine (Fig. 1c).

Step 6: First Level of Treatment
The first level of treatment begins with an arthroscopic arthrocentesis (the lysis and lavage stage), which is done with 120-200 cc of irrigation fluid with turbulent flow in order to remove inflammatory mediators, as well as lysis of any small adhesions that may be present.
This is followed by the diagnostic sweep (Fig. 2), which provides an accurate diagnosis of normal and pathologic conditions in the superior joint space, through describing the seven points of interest as well as joint motion.

Step 7: The second level of treatment
Direct injection of intra-articular medications (steroids, hyaluronic acid, PRP) as indicated in certain clinical cases.

Step 8: Closure
Once the procedure is completed, all instrumentations are removed while maintaining direct pressure over the puncture sites and then the patient's head is elevated slightly to aid in hemostasis.
The fossa puncture site is closed using single 5-0 or 6-0 nylon sutures and then covered with antibiotic ointment and a spot Band-Aid. Finally, the ear wick is removed and the external ear canal is examined.

Step 9: Jaw Manipulation
With the patient's head faced upwards, the surgeon manipulates and stretches the mandible and the range of motion is observed.
At this point, it is worth mentioning that multiple studies reported an 80-90% success rate with arthroscopic lysis

Fig. 1: Fossa portal puncture –Skin landmark (a), for the safe placement of the first puncture with a sharp trocar (b) and observation of the flow of irrigation fluid through the outflow 22-G needle (c)

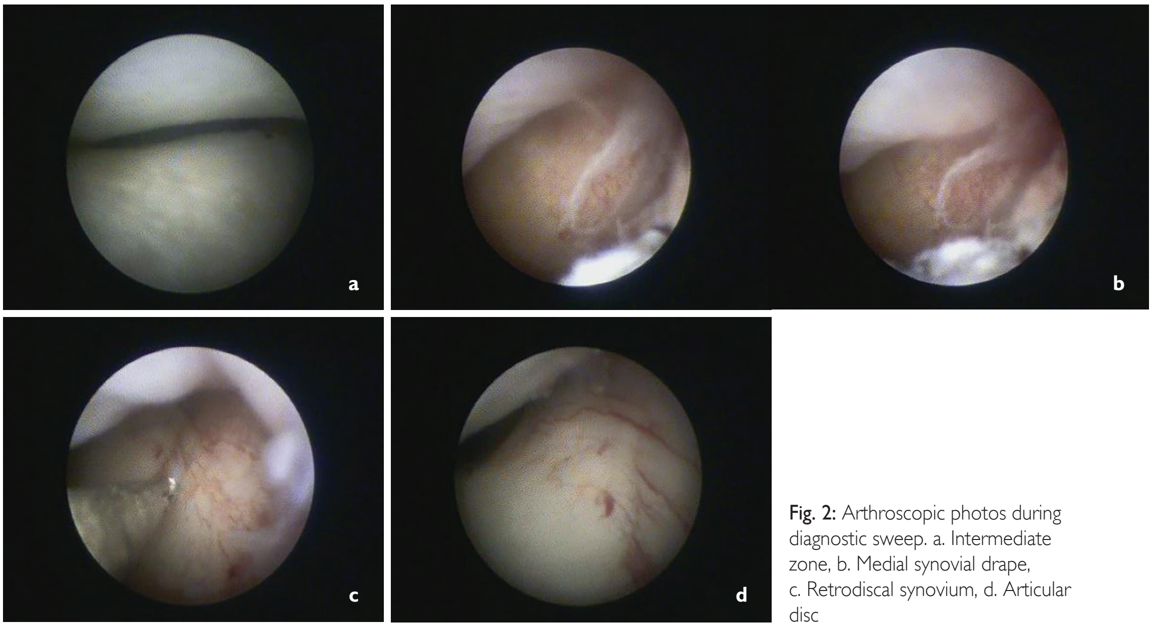

Fig. 2: Arthroscopic photos during diagnostic sweep. a. Intermediate zone, b. Medial synovial drape, c. Retrodiscal synovium, d. Articular disc

and lavage for the management of patients who were suffering from painful limited mouth opening (34, 35). Finally, studies with 5 and 10 years of follow-up also show that arthroscopic lysis and lavage is successful for all stages of internal derangement and that the results are equivalent to those acquired from TMJ open surgery (Murakami et al.).

Technique: Operative TMJ Arthroscopy

(Double-Puncture Arthroscopy) (27, 28, 29, 30, 31, 32, 33, 43)

Step 1: Intubation

This technique is always carried out under general anesthesia via nasotracheal intubation.

Step 2: Patient Examination and Preparation

The patient is examined under general anesthesia. Then the patient is positioned, prepared and draped in the usual fashion for TMJ arthroscopy. A sterile atraumatic ear wick is placed in the ear for protection. Afterwards, inspection and palpation of the TMJ is done in order to determine the position of the condylar head through passive movement of the joint. Then a straight line is drawn between the center of the tragus and the lateral canthus, followed by making a point on the line, 10 mm away from the tragus and 2 mm below it. This is point A – First trocar site. Then a point is made on the line, 20 mm away from the tragus and a perpendicular line is drawn 10 mm downwards. This is point B – Second trocar site (Fig. 3).

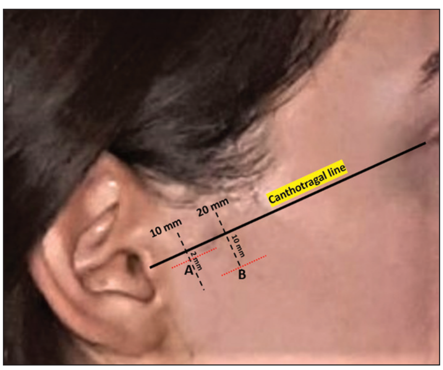

Fig. 3: Skin landmarks for the safe placement of the trocars.

Step 3:

Step 3: In this phase, steps 2 through 6 of the primary arthroscopy technique are repeated (The Fossa Portal Puncture with Lysis and Lavage and then the diagnostic sweep).

Step 4: Second Cannula Puncture

After the completion of the diagnostic sweep, the second puncture has to be placed precisely in the most anterior and lateral corner of the SJS to gain maximum flexibility of the operative cannula (20-25 mm anterior to the middle tragus). While the condyle is being positioned in the fossa, the irrigation needle is removed and then the puncture site is located according to the triangulation technique. The vectors of instrument orientation create an equilateral triangle that enables a repeatable and safe pattern of placement for the second puncture. This access point will provide an outflow portal for irrigation and the ability to insert tools into the space of the joint. In a similar fashion to that used for the fossa puncture, insufflation of the joint with 2-3 mL of irrigation fluid is performed. Afterwards, the trocar/cannula penetrates perpendicular and then continues in the same direction. The trocar is rotated through the skin and it is advanced until bone contact is made at the level between the anterior aspect of the anterior slope of the articular eminence and the zygomatic arch. Next, the trocar/cannula is rotated through the capsule and the synovium. At this point, the trocar is noticed on the monitor entering the joint space. Once it is intra-articular, the trocar is removed and drainage of the irrigating fluid is observed through the cannula.

Step 5: Advanced Arthroscopic Procedures (Level II and III of TMJ arthroscopy)
1. Synovial biopsy
2. Arthroscopic debridement
3. Arthroscopic diskopexy

Step 6: Steps 8 and 9 of the primary arthroscopy technique are repeated (Closure and Jaw manipulation).

TMJ arthroscopy complications

As in every surgical procedure, similarly in TMJ arthroscopy complications may occur, although they are very rare and minor with an overall incidence of approximately 1.3 % (6).
Generally, complications can be reduced with careful surgical technique. Our aim is not just to mention the complications, but also to provide useful knowledge and some tips in order to avoid them and/or deal with them.
The most frequent complication is scuffing of the fibrocartilage during the placement of the instruments into the joint (iatrogenic injury). It should be noted that trauma to this tissue can lead to hypomobility of the joint (36, 37). Therefore, in order to reduce the incidence of this complication, avoid repeated attempts of the insertion of the irrigation needle and pay attention to the direction of the insertion of the trocar, as well as the intra-articular manipulation.
When minor scuffing occurs, normally the fibrocartilage regenerates without any long-term problems. If significant scuffing occurs during surgery, it impairs visibility and may result in a misdiagnosis of chondral degeneration.
Leakage of the irrigating fluid into the surrounding tissues may occur. A severe complication such as pulmonary edema has also been reported in the literature after TMJ arthroscopy (very rarely) (38). The periorbital tissues, the masseter and the soft palate are common sites of fluid accumulation. Evaluation of the oral cavity for soft-tissue edema post-operatively is mandatory (deviation of the uvula may indicate the phenomenon of extravasation). Prevention of this complication requires proper placement of cannulas and caution in joint lavage in order to avoid the phenomenon of extravasation.
Temporary facial nerve paresis can be seen postoperatively, in most cases due to local anesthetic injection around the major branches of the facial nerve. Prolonged facial nerve paresis may be the result of a scar tissue formation near the facial nerve branches. Iatrogenic injury due to the placement of the portals may also result in facial nerve damage (it can be avoided with careful technique) (39, 40).
Injury to other significant trigeminal nerve branches (auriculotemporal nerve, lingual nerve, inferior alveolar nerve) (41). Prevention of this complication requires precise puncture measurement anterior to the tragus and avoiding medial drape perforation, that may occur by overextending the cannula by more than 35 mm. Nerve injuries are rare and most patients regain nerve function within 6 months postoperatively.
Injury to the vestibulocochlear nerve and dysfunction of the auditory system may also occur during arthroscopy (41). Therefore, it is advisable to angulate the trocars anteriorly, with the same angulation of the tragus to avoid any perforation into the middle ear. In addition, do not advance the arthroscope more than 25 mm.
Tympanic membrane perforation (41). Although it might be rare, it has been mentioned in the literature. If it occurs, our advice is to stop the procedure and obtain an intraoperative ENT consultation. Usually if the tympanic membrane injury is less than 30% of the surface, healing should occur with no consequences. Any minor ear hemorrhage is controlled by bipolar cautery, while the external auditory meatus is treated with hydrocortisone drops for a period of up to 2 weeks.
Cartilaginous or bony ear canal damage is also possible (36).
Bleeding: Injury to major vascular structures may also occur during arthroscopy (41, 42).
The vertical distance of the maxillary artery is far away from the usual arthroscopic approaches (approximately 20.3 mm). Although a rare complication, it may lead to an Arteriovenous (AV) fistula with a pathognomonic patient complaint of a persistent hissing sound, which requires medical attention and treatment.
Bleeding from the medial aspect of the joint can be crucial, since it can involve the middle meningeal artery, which may run within 2 mm of the medial joint surface. In order to prevent this complication, caution is taken to avoid medial drape perforation.
Bleeding may also occur during the penetration of the superficial tissues (from branches of the temporal vein during puncture) which has been noted in 2% of cases. This complication is managed by applying controlled pressure. In rare incidents, injury to these vessels may also result in an AV fistula or even in a pseudoaneurysm, which should be managed surgically (43).
Articular disc perforation (41). Avoid any deviation from the standard and safe technique of capsular puncture.
Hemarthrosis. It is a difficult intraoperative problem to manage therefore it should be prevented by not tearing the superficial temporal artery. Minor hemorrhage can be tamponaded with pressure irrigation. Excessive hemorrhage can be difficult to manage:

Fig. 4: Sialoendoscopy tools

Initially

- Increase irrigation pressure
- Inject a small amount of hyaluronic acid into the joint space
- Use cautery or a laser for the bleeding area
- Inject local anesthetic solution with vasoconstrictor into the bleeding site

Additional methods

- All instruments are removed while direct palmar external pressure is applied for 5 minutes. For added pressure, the condyle is seated in fossa if the source of the bleeding is located posteriorly and it is protruded if bleeding anteriorly.
- The use of a number 4 size catheter balloon is inserted through a working portal and inflated with normal saline, which is left in place for 5 minutes.

If all the above mentioned measures are not successful, the joint is approached via the open technique for final therapeutic arrangement.

Perforation into the glenoid fossa (41, 43)

This is a severe complication. In order to avoid it, control the direction of the instruments towards the tubercle and away from the fossa. Also, extreme caution has to be taken while attempting the triangulation technique. If the skull base is perforated, an intraoperative neurosurgical consultation is recommended. Most Cerebrospinal Fluid (CSF) leaks will heal spontaneously. If CSF continues to accumulate in the wound or drain through the incision, a pressure dressing should be applied with head elevation and the patient should remain under hospitalization. A leak that persists for more than 48 hours is an absolute indication for neurosurgery consultation with a lumbar subarachnoid drain placement and a CT scan documentation of the leak site.

Infection (41)

Prevention of this complication can be done in a proper sterile surgical environment and with the use of all the appropriate techniques, proper perioperative antibiotic prophylaxis, high-volume irrigation and the absence of any adjacent skin infections. If the complication occurs, administration of cephalosporin is advisable for a period of 7 days. If the infection persists, exploration of the area under local anesthesia with the removal of any residual sutures and further cephalosporin administration may be helpful for a period of 7 days. In the presence of purulence, incision and drainage are necessary with copious antibiotic solution lavage, debridement with drainage placement (it can be removed after 3 days) and IV antibiotic coverage.

Fragments of instrumentation is a very rare complication (43, 44).

Sialoendoscopy

Introduction

The insertion of a scope into a salivary gland duct was first used and described in 1990 and 1991 by Dr. Katz. The sialoendoscopy technique is still evolving as optics and instrumentation continue to advance (Fig. 4) (45, 46). Nahlieli and Marchal have contributed remarkably to this evolution and they have separately announced success rates of over 80% in treating salivary gland obstructive pathologic conditions by utilizing MIS techniques (47). It is worth mentioning that McCain, Maria

Troulis and M. Papadaki published their results of the first multicenter comprehensive study of sialoendoscopic techniques in the United States of America in 2007, thus contributing to the development of sialoendoscopy techniques as well (48).

In the past, traditional treatment of salivary gland obstructive pathologic conditions was restricted only to open surgery (parotid and submandibular sialadenectomy). Despite the fact that complications of salivary gland ablation procedures occur at a low rate (2% - 9%), some of these are problematic for patients and physicians, namely (49, 50):
a) Excessive scarring
b) Great auricular nerve numbness
c) Nerve damage (hypoglossal, lingual, and facial nerve)
d) Frey syndrome (Auriculotemporal syndrome)
e) Hemorrhage
f) Sialocele
g) Salivary fistula
h) xerostomia
In order to avoid these complications, MIS procedures are now being performed. The procedure of sialoendoscopy gives us the opportunity to diagnose and cure salivary gland obstructive diseases without unnecessary examinations and more harmful invasive operations. Moreover, it allows the visualization of the salivary ductal system and the identification of the cause of the obstruction.

Chronology: From the flexible/rigid endoscope to the semirigid/semiflexible endoscope

Dr Katz began Sialoendoscopy in 1990, with the use of a flexible mini endoscope, combined with a blind technique, in order to grasp the obstruction from the salivary gland ductal system. Dr. Arzoz was the next one to announce high success rates using a rigid urethroscope for observing the duct. The rigid endoscope resolved the issue with the lighting during the procedure. In 1994, Nahlieli and colleagues (17) used a 2.7-mm rigid TMJ arthroscope by introducing it into the salivary gland duct and with suction they brought the sialolith forward so that it could be securely extracted. The rigid endoscope occasionally produced trauma to the duct and other soft tissues (51, 52). Marchal presented the semiflexible endoscope in 1998. In 1999, following a small number of changes, he published the results of his experience of using a 1.3-mm semiflexible sialendoscope (53, 54). It is worth noting that the irrigation channel was imported in 1999 by Prof. Nahlieli (51). Eventually, the rigid endoscope was replaced by a semirigid/semiflexible endoscope with the addition of a working channel and refined endoscope diameter in order to be more practical, effective and safe.
Many authors prefer an endoscope diameter with a 1.3-mm working channel (45). Let it be noted that for diagnostic purposes only, an endoscope diameter of 0.9 mm can also be used.

Diagnosis and management of salivary gland obstruction pathology

Obstructive sialadenitis (with or without sialolithiasis) is the most common inflammatory disorder of the major salivary glands. Sialolithiasis is one of the major causes of sialadenitis, most often seen in adults, but it may also appear in children (56).
Approximately 60-70% of salivary obstructive disorders have the stones as a causative factor. Other causes can be strictures, kinks, polyps, foreign bodies or mucus plugs57-59. Salivary gland stones may be detected in 1.2% of the general population.
Approximately 80-90% of sialoliths are discovered within the submandibular gland, 5-15% within the parotid gland and only 2-5 % of them in the sublingual gland. Stones may also be very rarely diagnosed in the minor salivary glands. It should be noted that submandibular sialoliths are located in the distal section of the Wharton duct or at the hilum in 90% of cases.
Effective treatment depends on the surgeon's skills for an accurate diagnosis and in the event of sialolith presence, in order to precisely localize the obstruction site, estimate its dimension and assess the mobility or immobility status of the stone.

In order to diagnose salivary stones, it is useful to follow some clinicoradiological steps:

– Proposed by the Herman Ostrow Dental School, University of Southern California, USA –

- Bimanual palpation (Always in a posterior to anterior manner along the route of the implicated duct)
- Plain Film Radiographs (20% of submandibular gland stones, 60% of parotid gland stones and 80% of sublingual gland stones are poorly calcified and undetectable with plain radiographs (60))
- Sialography – conventional or combined (A catheter is inserted through the duct opening and water-based iodine contrast is infused. Afterwards a panoramic, CBCT or CT image will be performed or an MRI. The stone will appear as an empty space on the sialography image.
- Ultrasound (Lately, it is extensively used as a first-line diagnostic method of a salivary gland stone. Moreover no radiation is needed, therefore it is safe and it can be repeated. It costs much less than any other imaging modality and it can also help detect large sialoliths)
- CT scan (It has higher sensitivity than plain radiographic films for discovering salivary stones. A slice thickness of 0.2– 0.5 mm is used)

- CBCT scan (it has the advantages of reduced superimpositions and distortions of the panoramic x-ray image and reduced radiation exposure over CT)
- Sialoendoscopy (it can be used as a diagnostic and therapeutic technique for salivary gland diseases e.g. stones, strictures, kinks. Its advantages include visualization of the duct canal and stone removal at the same time, if that it is possible.)

Up to date diagnostic steps for salivary gland stones

Many authors recommend ultrasound as the first choice of inspection. If there is an obstruction, its position and diameter relating to the proximal duct can be seen by stimulating the salivary flow with a sialagogue (e.g. vitamin C tablets (61)). It must however be noted that the use of an ultrasound may be limited in the deep part of the submandibular gland.

Computed tomography (CT) imaging can be useful in cases where ultrasound fails to recognize a stone. Diagnostic value restrictions of ultrasound and CT scans include discrimination of non-echogenic stone from stricture, stenosis length and duct diameter distal to the obstruction site. Conventional sialography, CBCT-sialography and MRI-sialography can assist in overlapping these issues.

McGurk and Nahlieli suggest an ultrasound and conventional sialography on the initial assessment in order to evaluate duct structure, so that the basket retrieval technique is avoided, if strictures are present. Others (the Erlangen group-Germany) prefer an ultrasound and an MRI-sialography as the primary diagnostic investigation technique.

In many clinical cases, traditional diagnostic images are still unavoidable for "freezing out" conducive pathologic conditions. Diagnostic Sialoendoscopy can occasionally replace the necessity for expensive and frequently non-diagnostic examinations.

Definitive treatment of sialolithiasis is done with the removal of sialoliths from the salivary gland, either by using endoscopic techniques (with a general success rate greater than 80%), sialodochoplasty or open surgery with the excision of the affected salivary gland. It is preferable, whenever possible, to use endoscopic techniques in order to preserve the salivary gland and avoid all the complications associated with the surgical removal of the affected salivary gland.

Management of obstructive salivary disorder due to stones

The management of the obstructive salivary disorder due to stones depends on the following features (Witt et al.: Minimally Invasive Salivary Calculi):

a) the size of the stone
b) the location of the stone (proximal, distal, or intraparenchymal position)
c) the number of stones
d) the impaction or mobility status of the stone
e) the surgeon's experience

Sialoliths that are observed either within the gland or extraglandular are not manageable with endoscopic removal techniques. In these specific cases, stones are extracted with the excision of the gland and sialodochoplasty (62).

There are also other situations in which Sialoendoscopy is not warranted such as:

a) Non-obstructive sialadenitis that can be resolved with antibiotic drugs
b) Automatic discharge of the obstruction
c) Large stone magnitude
d) Proximal position of the stone (e.g. located within the hilum of the duct)
e) Trismus from TMJ pathologic conditions or salivary gland active infection are contraindications for sialoendoscopy (6)

For a regular obstruction, if conservative management is unsuccessful (sialagogues, massage, heat, fluids, and antibiotics) sialoendoscopy may be considered. If there are no stones, the ductal system has to be inspected thoroughly for kinks, strictures or any other source of obstruction as far proximally as possible.

Marchal and colleagues found that salivary glands have functional activity, even after a chronic obstructive disease (63). This fact gives, to some patients, the opportunity to undergo a sialoendoscopy procedure in order to rescue the gland.

Many patients and physicians frequently ask whether all instances of salivary stones are removable with MIS. The only way to answer this question is by performing the sialoendoscopy, because only then can we see/touch/try to mobilize the stone and remove it. In cases of small, floating, single or multiple stones it is usually easy to grab them and extract them with forceps/baskets within a few minutes. In cases of large, fixed or hidden stones sometimes it is impossible to have any success at all. In these situations open surgery or sialodochoplasty is considered, as mentioned above. Additionally, if bigger sialoliths are present and/or the location is more proximal, lithotripsy is also an option. Extracorporeal shock wave lithotripsy (ESWL) is a non-invasive technique (first mentioned in the urologic literature) that can be used for the obstructive salivary gland disease due to large sized stones. Problems include the necessity for a second treatment and the retrieval of the sialoliths (with duct bougienage and the use of the Dormia basket extraction) that do not flow freely out of the duct (64, 65, 66, 67, 68). In relation to parotid duct stones, the long-term outcome for ESWL is that 50% of patients are left free of stones and 80% of them are left free of symptoms. In comparison, for submandibular stones, ESWL is less effective with 30% of patients being left free of stones. Intracorporeal lithotripsy (endoscopically assisted) is a minimally invasive technique that can also be utilized in the treatment of salivary gland large sized stones (69). For this purpose, a 0.8-mm diameter laser lithotripter probe is inserted in the working channel in order to remove the stone. This technique was first reported by Dr. Konigsberger (70) in 1990 and successful results were published by Dr. Arzoz (71) in 1994.

Sialoendoscopy Techniques

Diagnostic Sialoendoscopy

Preoperative clinicoradiographic assessment of the patient is always essential in order to guarantee the success of the procedure (6), which is carried out under local anesthesia, IV heavy sedation (intravenous midazolam, 5 mg) (72) or general anesthesia (Nasotracheal intubation). Difficult and complex cases are better managed under a general anesthesia environment which is well regulated and also provides the ability for the alteration to an open surgery procedure, if required (Gillespie et al.).

Initial surgical tips: Many surgeons insert a probe in the duct before the injection of the local anesthetic, because of the distortion caused by the injection (73). Moreover, the use of a proper mouth prop during the procedure is important for providing an unobstructed field of view on the floor of the mouth.

Insertion of the endoscope into the duct papilla (which is the narrowest part of the duct) may sometimes be demanding (74). The natural access to the salivary ducts is the punctum, which is found in most cases at the center of the caruncula or papilla. To expose the sublingual caruncula, the ventral surface of the tongue must be elevated towards the palate. This can be performed with conventional retraction or with the placement of one or two 2-0 silk sutures paramedian through the lingual apex. The papilla is very gently manipulated with dental pick-ups ("cotton pliers") and instrumented. Be aware that no suction should be applied to the papilla during the procedure. For patients with submandibular gland obstruction, blue methylene is useful for locating and cannulating the duct (75).

After locating the punctum, the progressive dilating process follows using conical dilators and salivary probes of increasing diameter, in order to prepare the duct for the insertion of the endoscope (Fig. 5a). Most authors prefer Marchal salivary probes. A duct dilated to a number 3 or number 4 size probe should facilitate the 1.3-mm Storz-Marchal endoscope. The scope is then advanced as far proximally into the duct as permitted (to the obstruction or into the gland hilum). If the ostium is too small for dilators, a guidewire and bougie dilation may be performed (76). Guidewire introduction through the working channel helps the insertion of the endoscope through a firm papilla (77).

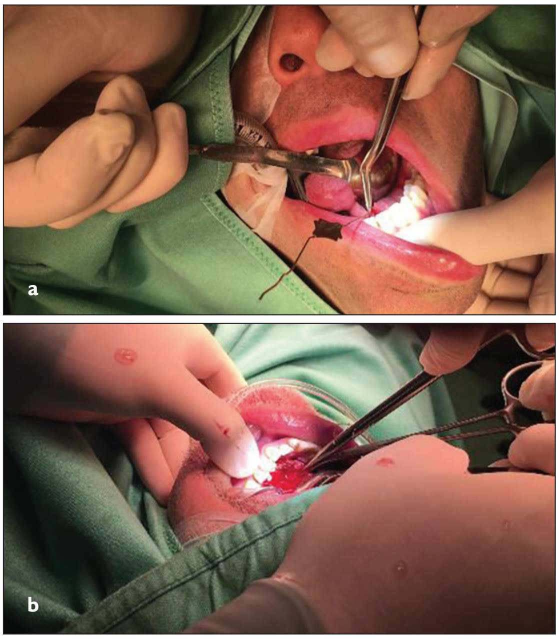

Fig. 5: a) The dilating process of the submandibular duct, b) Surgical exploration and detection of the anterior part of the submandibular duct.

If all the above maneuvers fail and the duct does not dilate (Papilla stenosis of Wharton's duct), a papillotomy ("cut-down" dichotomy approach) is performed. A 5 mm incision with an 11-blade or CO2 Laser is done directly posterior to the orifice (along the superior surface of the duct) thus creating a larger opening hole in order to insert the scope. If papillotomy also fails, then surgical dissection and exposure of the anterior part of the duct using the microsurgical technique together with longitudinal incision will facilitate the insertion of the intraluminal endoscope (Fig. 5b).

Irrigation with normal saline helps during the dilation process, the placement of the endoscope and the navigation of the duct. It is established with the appliance of intravenous tubing to the irrigation port attached to a 50- to 100-mL syringe. It is advisable that in cases of chronic sialadenitis, abundant irrigation is helpful during all the phases of the sialoendoscopy procedure.

There are many factors that can make ductal access and dilation practically impossible such as:

- Caruncula inflammation
- Papilla stenosis or calcification
- Previous gland and/or duct surgery
- Preoperative administration of antisialagogues
- Ductal orifice sphincter spasm, duct stenosis or fibrosis
- Abnormal duct convolutions and duct occlusion or obstruction

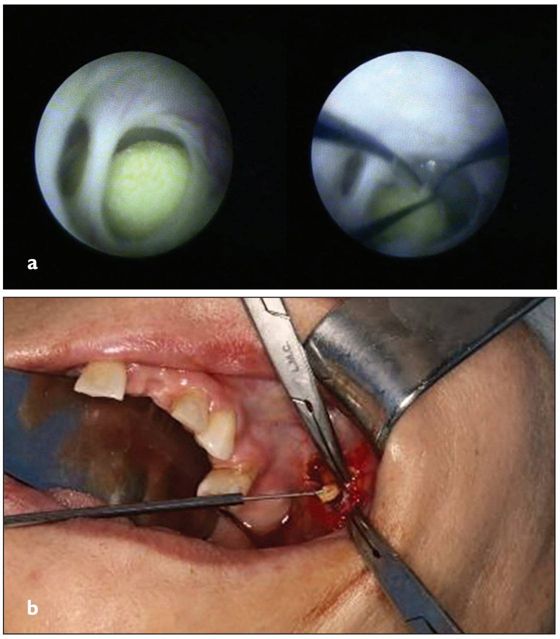

Fig. 6: (a) Sialolith of a submandibular duct and wire basket usage for retrieval, (b) Wire basket retrieval of a sialolith from the parotid duct.

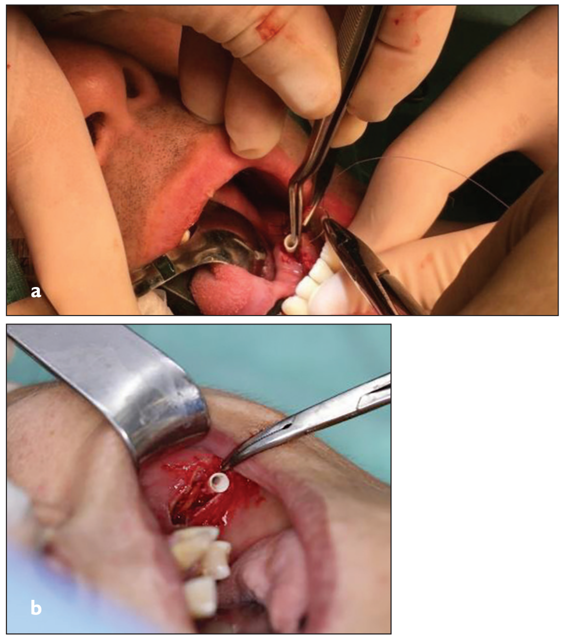

Fig. 7: (a) Stent placement in the submandibular duct, (b) Stent placement in the parotid duct.

Something important that has to be mentioned is that patients with duct stenosis should be timely programmed as soon as possible in the operative day, in order to prevent dehydration aggravation connected with NPO status, which minimizes the salivary flow thus making ostial recognition even more challenging.

Interventional sialoendoscopy

For interventional sialoendoscopy we follow the same approach as mentioned above for diagnostic sialoendoscopy. Furthermore, it includes therapeutic surgical movements for resolving the cause of an obstructive salivary duct. Kinks in the duct can be bypassed with the help of a guidewire. If the obstruction due to a stone is seen, a Fogarty catheter can be placed through the working port beyond the obstruction site in order for it to be retrieved. Usually a basket is used (Fig. 6). If a laser device is available, laser lithotripsy can also be performed in cases where the stone is big in size (6, 78, 79). Calculi of small diameter can be grasped with forceps, wire baskets or graspers, which are instruments that are manipulated through the working cannula of the endoscope. The obstructive mucous plug or sialolith can be dislodged with gentle retraction and removal of the endoscope. In calculus of diameter greater than 5-6 mm, a papillotomy is necessary in most cases for retrieval, because usually the orifice sphincter will not dilate more than 3-4 mm.

At the end of the procedure (either diagnostic or interventional sialoendoscopy), before placing the stent many authors inject 8 mg of dexamethasone into the duct to reduce postoperative swelling (72).

STENT insertion

To prevent postoperative ductal lumen stenosis/obstruction, due to edema, a 2-3 cm long stent is inserted into the duct and stabilized with a provisional non-absorbable suture (e.g. 4-0/5-0 proline) for 7-10 days to promote the healing process and the drainage of the salivary gland (Fig.7) (72). The stent also prevents the extravasation phenomenon (with subsequent ranula formation) and decreases the possibility of recurrence of sialolithiasis. Moreover, it usually corrects most unfavorable angles and convolutions of the Wharton duct around the lingual nerve and the mylohyoid muscle (which is one of the main causes of obstruction according to the mechanical theory). Most authors recommend that the stent should be kept in place for at least 3-4 weeks postoperatively, which is an approach we agree with as well.

The patient is then given appropriate antibiotics (i.e. cephalosporin or Augmentin or clindamycin in case of allergy to penicillin) for 7 days, NSAIDs together with 20 mg of prednisone for 3 days and postoperative instructions in order to optimize salivary flow. In patients affected with autoimmune diseases (e.g. Sjogren syndrome-SS, systemic lupus erythematosus – SLE, etc.) 100 mg of hydrocortisone are injected under direct vision into the duct at the end of the endoscopy (80).

Evidently not all stones are amenable for endoscopic removal. In the following section, we will explain, as briefly as possible, the alternative therapeutic options for every possible clinical situation, in relation to submandibular and parotid salivary glands relating to the location and size of the stones.

Table 3: Management of Submandibular gland stones after the failure of conservative treatment

	Distal Stones <5 mm	**Proximal Stones <5 mm, Mobile, or Palpable Intraparenchymal**	**Proximal Stones >5-6 mm, Mobile, or Palpable Intraparenchymal**
1st-line approach	Transoral (McGurk, Nahlieli, Witt)	Interventional sialendoscopy (all authors)	Transoral approach, limited duct incision (McGurk, Nahlieli, Witt), duct incision papilla to hilum (Erlangen group)
1st-line approach	Interventional sialendoscopy (Erlangen group)		
2nd-line approach	Transoral approach (Erlangen group)	Transoral approach (all authors), limited duct incision (McGurk, Nahlieli, Witt), duct incision papilla to hilum (Erlangen group)	ESWL (Erlangen group, Nahlieli; McGurk does not advocate ESWL for submandibular stones)

ESWL = extracorporeal shock wave lithotripsy.

- Firstly, we will focus on submandibular gland stones, found on the distal or the proximal duct (Table 3). Various techniques are available and the decision is made according to the personal preference of each physician.

A. Submandibular Stones, Distal and Proximal Duct

* Bear in mind that the use of the Extracorporeal Shock Wave Laser (ESWL) for submandibular sialoliths is not equable as it is for parotid sialoliths.

The transoral approach - preferred by McGurk & Nahlieli

Distal stones less than 5 mm, located close to the Wharton's duct punctum (1 cm less than the orifice) can be managed with a longitudinal cut of the duct using a needle tip of electrosurgical unit. Then the removal of the stone is performed, followed by sialendoscopy and lavage. The duct heals with secondary intention and stents are usually not required for preventing stenosis (81), although many authors recommend placing a stent for the same reasons that are mentioned above.

Interventional sialoendoscopy – preferred by the Erlangen group

Alternatively, the primary therapy for distal stones less than 5 mm can be achieved by performing an interventional sialendoscopy (82). However, papillotomy is usually a mandatory surgical step because the narrowest part of the duct is the ostium.

Interventional sialoendoscopy uses baskets, balloons or graspers that permit sialolith removal via the working channel of an endoscope for mobile proximal submandibular stones less than 5 mm (which is the favored approach of Nahlieli, Witt, McGurk and the Erlangen group) (83). The basket is always opened behind the stone, otherwise it runs the risk of entrapment for large fixed stones (84). New baskets have been recently invented that permit the stone to be grasped and released, if it is immobile or too large for it to be retrieved. Balloons (preferred by Nahlieli) can be utilized for removing small sized stones by passing the uninflated balloon distal to the stone, then inflating the balloon and finally withdrawing it (85). Balloons and forceps are inserted through the working channel of an endoscope. Another technique presented by Nahlieli is a cutdown approach to Wharton's duct. In this technique the duct is seen and opened surgically. Afterwards, a balloon or forceps can be inserted, not through the working channel but next to the endoscope (85).

Geisthoff and Maune have reported the usage of a US-guided mechanical stone fragmentation technique (sonoguide forceps) (86). The advantage is that larger size forceps may be used under ultrasound guidance, without the need of a sialendoscope, which restricts the size of the forceps. Distal stones are more effectively treated with this technique compared with stones located in the parenchyma. Following this step, Nahlieli suggests the

Table 4: Management of Parotid gland stones after the failure of conservative treatment

	Distal Stones <4-5 mm	**Proximal Stones <4-5 mm or Mobile, Visible, Intraparen-chymal**	**Proximal Stones >5-6 mm and <10 mm**
1st-line approach	Interventional sialendoscopy (all authors)	Interventional sialendoscopy (all authors)	ESWL + SE (Erlangen group, McGurk, Nahlieli)
1st-line approach			Combined sialendoscopic/open approach (Witt)
2nd-line approach	ESWL + SE (Erlangen group, McGurk, Nahlieli)	ESWL + SE (Erlangen group, McGurk, Nahlieli)	Combined sialendoscopic/open approach (Erlangen group, McGurk, Nahlieli)
2nd-line approach	Combined sialendoscopic/open approach (Witt)	Combined sialendoscopic/open approach (Witt)	
3nd-line approach	Combined sialendoscopic/open approach (Erlangen group, McGurk, Nahlieli)	Combined sialendoscopic/open approach (Erlangen group, McGurk, Nahlieli)	

ESWL + SE = extracorporeal shock wave lithotripsy + sialendoscopy.

use of suction at the working channel in order to take out dust-like sialolith pieces in selected cases (83).

Stones greater than 5 mm, located in the proximal Wharton's duct, can be extracted using Nahlieli et al.'s ductal stretching procedure (87) and limited duct incision. Modifications have been introduced by McGurk, which provide a safer surgical approach (ductal & lingual nerve protection), with the use of the Ferguson mouth prop and lateral retraction of the sublingual gland with sutures passing through the teeth (88). The Erlangen group recommends a different technique by cutting the duct from the punctum to the hilum. Then, the duct is securely sutured to the floor of the mouth without a risk for ductal stenosis (89). Reconstruction of the duct proximally is technically problematic, therefore letting it open will possibly not result in an in ill effect. Marchall described the usage of a guidewire through the working channel of a sialendoscope passing through the ductotomy, as an alternative option. Then the sialendoscope is withdrawn and a stent is inserted over the guidewire and then stabilized to the papilla with non-absorbable suture, leaving it in place for 3 to 4 weeks (90).

Proximal submandibular stones greater than 5 mm, which are incapable of being removed with transoral procedures, can be managed with ESWL followed by sialendoscopy (ESWL and SE which are favored by the Erlangen group and Nahlieli) (82, 85). McGurk does not use ESWL for submandibular stones.

It is worth mentioning that ESWL is not an FDA approved technique in the United States of America and it is not being used. In the USA, robotic-assisted transoral removal of large and impacted sialoliths offers an alternative treatment option in some cases (91).

- Secondly, we will focus on parotid gland stones, found on distal and proximal duct (Table 4).

B. Parotid Stones: Distal and Proximal Duct

Interventional sialendoscopy and basket retrieval of proximal and distal parotid sialoliths less than 4 to 5 mm is the treatment of choice recommended by all authors. Distal parotid stones less than 5 mm, which are incapable of being removed sialoendoscopically and stones greater than 5 mm, can be extracted only if they are finally seen at the duct orifice. Be cautious and avoid any strive when dissecting the parotid duct along its oral origin because it may result in stenosis.

Stones less than 4 to 5 mm which are not responsive to interventional sialendoscopy and stones greater than

Table 5: Management of intraparenchymal non-palpable or impacted stones greater than 5 mm after the failure of conservative treatment

	Submandibular Stones	Parotid Stones
1st-line approach	ESWL + SE (Erlangen group, Nahlieli)	ESWL + SE for stones <10 mm (Erlangen group, McGurk, Nahlieli)
1st-line approach	Sialadenectomy (Witt)	Sialadenectomy (Witt)
2nd-line approach	Sialadenectomy (Erlangen group, Nahlieli)	Sialadenectomy (Erlangen group, McGurk, Nahlieli)

ESWL + SE = extracorporeal shock wave lithotripsy + sialendoscopy.

5 mm are managed with ESWL and SE (favored by the Erlangen group, McGurk, and Nahlieli) (81, 82, 85).
In the USA, where ESWL is not applicable, a gland-sparing technique for stones greater than 5 mm is applied on the Stensen's duct. A combined approach of external parotid skin incision (with nerve monitoring) and sialendoscopy is performed. In selected cases with bigger stones, intraoperative ultrasound can be useful. The sialolith can be recognized through the endoscope or with an ultrasound (when stenosis appears distal to the stone). The parotid duct crosses several branches of the facial nerve. A colored silicone tube will assist in stabilizing the duct (described and proposed by Marchall). An external parotid approach with longitudinal cutting of the Stensen's duct is followed by closure of the duct using 6-0 or 7-0 Prolene absorbable sutures. If duct constriction (stenosis) occurs, it can be managed with a vein graft ductoplasty patch. Backwards transoral irrigation pressure of the Stensen's duct with sterilesaline via the irrigation channel of the sialendoscope verifies a water-tight closure. Sometimes fibrin glue can also help to secure a salivary seal. A stent is inserted as the last step of the procedure, either from the external approach or via a sialendoscope forwarded on a guidewire and it remains in place for 3 to 4 weeks (90, 92).

- Thirdly, we will focus on both submandibular and parotid salivary gland stones found intraparenchymal and are non-palpable or impacted stones, with their size being greater than 5 mm (Table 5).

The Erlangen group and Nahlieli advocate ESWL and SE for both intraparenchymal, non-palpable or impacted submandibular and parotid stones (82, 85). On the other hand McGurk, favors ESWL and SE only for parotid stones (81).
Multiple intraparenchymal stones, incapable of being treated with conservative therapy, are managed with sialoadenectomy, which is recommended by all authors. In the USA, where ESWL is not being used, sialoadenectomy is proposed for immobile intraparenchymal stones and those not amenable to the above-mentioned gland-sparing techniques. A well performed sialoadenectomy has a low risk of complications to the cranial nerves (V, VII, and XII), without any concerns for xerostomia.

Complications in salivary gland endoscopy

Generally, the technique is harmless and effective, although complications may appear, with an incidence of less than 10% (most of them are minor) (93). Swelling of the gland is most often seen secondary to the abundant irrigation process. Additionally, failure to recognize and remove an impacted sialolith at the duct orifice can cause protracted swelling and infection (73). Extravasation of the irrigation fluid may occur on the floor of the mouth and the surrounding tissue due to an iatrogenic duct perforation (6). Transient paresthesia to the lingual nerve may also appear, usually due to the manipulation of an instrument away from the duct borders (94, 95). Moreover, temporary facial nerve palsy has been reported in the literature. Another complication is duct perforation (6) and if it is suspected, the endoscopic procedure should be abandoned and another treatment modality has to be applied. Failure to extract a stone can cause cellulitis of the gland and the surrounding tissue (73). An iatrogenic ranula or infection may also occur (95). The papilla (duct orifice) may be exposed to local trauma due to manipulation and become ulcerated or it may lead to bleeding and edema 6. Stricture of the duct has been observed with an incidence of 4% as a long-term complication (94, 95).
Salivary fistulas, sialocele, minor ductal tears, and minor hemorrhage have been also mentioned in the literature as possible complications (95).

The role of endoscopy in the treatment of facial fractures

Introduction

Kobayashi et al. reported the clinical application of the endoscope in maxillofacial fractures in 1995 (6). Accurate repair of complex craniomaxillofacial trauma is mandatory for functional and esthetic reasons. The access to the site of the fracture may sometimes be very difficult and endoscopic techniques are useful in such situations. The role of endoscopy in the treatment of facial fractures has been described in the literature and includes:

- Orbital floor fractures
- Mandibular angle fractures
- Condylar fractures
- Frontal sinus fractures
- Other maxillofacial injuries

Orbital Floor Fractures

Introduction

In conventional periorbital techniques, the posterior border of the orbital floor defect may not be clearly visible. Furthermore, these surgical approaches demand significant orbital soft tissue manipulation (96). Saunders et al. described the intra-oral transantral approach for the repair of orbital floor fractures in 1997 (97).

With the aid of an endoscope, a minimally invasive surgery can be executed in order to assess the magnitude and severity of the fracture through a transantral approach (intra-oral or trans-nasal fashion). In this literature review, we mainly focused on the intra-oral transantral approach, because it is the technique that most authors prefer to perform.

In bigger bone defects, repair only with the aid of an endoscope is challenging and it usually requires additional techniques, such as a combination of an inferior eyelid incision and endoscopy (Farwell and Strong, 2007; Strong et al., 2004). Moreover, if an implant placement is needed, lower eyelid approaches allow for an easy insertion, while the endoscope provides visualization of the posterior region (Nahlieli et al., 2007).

Benefits of the intra-oral trans-antral approach (96, 98)

The following advantages have been mentioned by many authors in the literature regarding the intra-oral trans-antral approach:

- Easy identification of the location/size of the defect (superior visualization)
- Decreased manipulation of the orbital contents and periorbital soft tissues
- Anatomic fracture reduction
- Lower risk of postoperative eyelid complications (ectropion/entropion, scleral show, eyelid edema)
- Good aesthetic and functional results
- It restores the orbital volume which is critical for globe position and visual acuity

The intra-oral trans-antral approach is a delicate technique that requires extensive training and experience (with a longer learning curve), in order to have comparable results with those of the traditional periorbital approaches (96).

The endoscopic approach in orbital floor fractures is also considered in patients where traditional approaches are contraindicated, such as those with hyphema, retinal detachment or globe injuries (99).

Complications of orbital floor fractures

Examples of complications of orbital floor fractures are hypoglobus, enophthalmos, diplopia (due to inferior rectus muscle entrapment, orbital soft tissue entrapment or both), Infraorbital Nerve (ION) paresthesia, limited ocular range of motion, orbital emphysema (due to communication with the maxillary sinus), orbital hemorrhage (risk for compressive optic neuropathy), globe rupture, hyphema, retinal edema, decreased visual acuity, amaurosis and loss of vision.

The Intra-Oral Trans-antral orbital floor fracture repair technique

In the literature, different approaches have been reported for the repair of orbital floor fractures, including a plain periorbital approach (subciliary, transconjunctival, midtarsal), a plain trans-antral approach or a combination of them (100, 101).

In the majority of cases, a purely trans-antral approach (without eyelid incision) is efficient for the repair of the orbital blow-out fracture and an implant may be inserted transantrally for the reconstruction of the orbital floor. However, caution must be taken when handling the intraorbital tissues from the antrum, in order to avoid impaction damage to the musculature, the periorbital content (orbital periosteum or orbital fascia) and the optic nerve. Another important surgical parameter is that in order to re-establish the orbital volume properly and avoid complications such as enophthalmos, it is always mandatory to rebuild the posterior projection of the orbital floor.

Last but not least, according to the intraoperative findings, the surgeon should always be ready to access the orbital floor via a traditional periorbital approach if necessary (100).

Technique

The forced duction test is performed with fine tissue forceps while the patient is under general anesthesia (oral endotracheal intubation). Corneal protection is imperative and it is obtained with the placement of a corneal shield with adequate lubricant.

A maxillary vestibular incision is performed (similar to the Caldwell-Luc incision) with needle electrocautery. Dissection is carried out subperiosteally in order to uncover the anterior and the lateral maxillary wall and the ION.

Afterwards, two osteotomies on the anterio-lateral antral wall are performed, with the positioning of two portals, each 6 to 7 mm in diameter (posterior antrostomy at the buttress area).The first one is for the insertion of the endoscope (vision portal) and the second one for the instruments (working portal). Most authors prefer to perform only one lateral antrostomy (Fig. 8) and use the all-in-one endoscope.

Then the endoscope is introduced into the maxillary sinus (the natural optical cavity). A 30° 4 mm in diameter with a xenon light source endoscope is recommended, although 0°, 45° or 70° endoscopes may also be utilized (6).

Subsequently a sinusotomy of the sinus roof/orbit floor is done with the aid of Blakesley nasal forceps (demucosalization), then the fracture site/margin is visualized and inspected, followed by the identification of the ION and the inferior rectus muscle. Lastly sharp bone fragments are removed if necessary (97).

After careful dissection, the orbital prolapsed tissue (fat, muscle) is repositioned cranially into the orbit. The orbital contents are gently pulled and pushed into the orbit with curved periosteal elevators. If the fractured pieces can be reduced, they can be stabilized with a titanium mesh or other material adapted on the antral side of the fracture. If not, an appropriate implant is placed on the orbital side of the fracture, so that both orbital volume and eye globe function are restored (For the fixation, 2 to 4 screws are used on the anterior and lateral maxillary sinus surfaces). Bear in mind that 1 screw is placed on the buttress area and 1 screw is placed on the pyriform fossa for providing maximum stabilization.

A forced duction test is repeated (under endoscopic vision in order to observe the inferior rectus muscle for entrapment or interference during movement). Reattachment and fixation of the osteotomized anterolateral maxillary sinus wall are then performed and the incision is usually closed with resorbable interrupted sutures (97, 98).

A postoperative CT scan is always performed in order to confirm the adequate orbital floor continuity and the level of correction.

The patient receives sinus precaution instructions, antibiotics, steroids and nasal decongestants. In rare cases, medications such as acetazolamide can help reduce the intraocular pressure 101.Usually, general improvement of the patient and resolution of the diplopia is seen after 48-72 hours.

The choice of method for supporting the orbital floor, after elevation of the orbital contents, remains debatable in the literature. According to this topic, in the literature it is well described the usage of autogenous bone (cranial bone, iliac crest, rib, anterior maxillary wall), alloplastic materials, titanium mesh or a resorbable plate/gelatin film to rebuild the orbital floor defect after trans-antral reduction. If a Titanium mesh plate is chosen, note that it can be shaped according to the size of the orbital floor with the help of curved periosteal elevators and a Foley catheter balloon and then stabilized with screws to the lateral surface. Most authors prefer the use of autogenous bone, because it gives the best clinical results with minimal to none at all complications and it is also the gold standard for this purpose (102).

Fig. 8: The trans-antral orbital floor fracture repair technique. Exposure of the lateral maxillary sinus wall via the modified Caldwell-Luc incision.

An updated protocol of virtual planning for minimally invasive management of internal orbital floor fractures (103)

This new protocol was introduced at the 21st Congress of the Italian Society for Maxillo-Facial Surgery and won the Costantino Giardino prize for scientific innovation (103).

The aim was to perform an accurate anatomical reduction of internal orbital floor fractures (Pure orbital blowout fractures, without orbital rim or other facial bones fractures). As mentioned earlier, autogenous bone graft is the ideal gold standard material for orbital floor defects, but at the same time the correct size and shape of the graft is also important for a stationary reconstruction.

The authors introduce a new protocol that combines endoscopy, virtual reality (CAD-CAM), and 3D printing.

Methodology: 14 patients with orbital floor fractures were selected. All patients underwent HR (high resolution)-CT scans for proper imaging of the bone defect. Virtual reconstruction of the defect was done and a 3D printed template was manufactured in order to supply intraoperative guidance in the graft harvesting phase, according to the orbital defect. The surgical guide was designed slightly bigger than the borders of the defect, in order to allow the harvesting of an oversized bone graft, so that it would fit over the orbital defect and be supported by the fracture outline. Postoperative CT scans were also performed in order to evaluate the orbital floor reconstruction.

Patients

Causes of injury were divided into 4 groups: assaults (42.9%), sport accidents (28.6%), falling from heights (14.9%) and car accidents (14.9%). Based on the time that had passed before surgical intervention, patients were subdivided into two groups: early surgical intervention (79%) and late surgical intervention (21%). In all patients preoperative clinical examination was performed, such as assessment of the visual acuity, movement of the eyeballs and exophthalmometry (measurement of the extent of protrusion of the eyeballs).

Indications for surgical reconstruction of orbital floor fractures included the following signs and symptoms: Post-traumatic constant diplopia, enophthalmos greater than 2 mm, vertical dystopia, CT scan verification of the infraorbital soft tissues, herniation into the maxillary sinus and a positive forced duction test.

All patients, 48 hours postoperatively, performed a CT scan. Follow-up was scheduled at 1 month, 2 months and 6 months.

Selection criteria: Class II and III only according to the classification of orbital floor fractures defined by Jaquiéry et al. in 2007.

The source of the bone graft was chosen according to Jaquiery's classification: in a Class II bone defect the maxillary sinus bone was a logical option, while for bigger defects such as in III, a donor area like the iliac crest bone was chosen.

Procedure: All cases were executed under general anesthesia using an intra-oral trans-antral approach. A 3 cm vestibular incision created access for the anterio-lateral wall of the maxillary sinus. The surgical guide was placed on the maxillary bone surface and a bone window was marked to equal the orbital wall defect. Using Piezoelectric surgery, a maxillary bone cut was done for inserting the endoscope. Then, the excised bone was arranged for reconstructing the orbital floor for Class II defects. For bone defects greater than 2cm, the iliac crest bone graft is the best choice as we mentioned earlier. 0º and 30º sinus endoscopes were used for the inspection of the herniated orbital content and the ION. With the usage of a periosteal elevator, the orbital soft tissues were gently pulled up into the orbital cavity. During the procedure, caution was taken in order to avoid iatrogenic injuries to the ION and the inferior rectus muscle. Note that in cases where a comminuted orbital floor fracture exists, bone fragments were removed so that they would not protrude into the orbit.

A bone graft was then placed via the maxillary sinus bone window and it was pulled upwards until its peripheral end matched the borders of the fracture and support for the orbital content was obtained.

Finally, a bio-collagen membrane was used on the maxillary opening and it was fixed with bone-anchored sutures and then the mucogingival junction was sutured water-tight.

Results & Discussion: Mild ION paresthesia was observed in only two cases. Preoperative diplopia was diagnosed in 12 patients preoperatively. Postoperatively, persistence diplopia was observed only in one patient. In all cases, preoperative enophthalmos was resolved after the surgery. Postoperative CT scans displayed anatomical reconstruction of the orbital floor.

The intraoral trans-maxillary approach decreases the risk of intraorbital vascular structures damage, since the reduction of the herniated orbital tissues is done from the bottom, through the maxillary sinus cavity.

It is worth mentioning that the presence of an intraorbital hematoma is a complication related to orbital fractures. With this technique, the archived wide opening of the anterolateral maxillary wall provides straightforward access for the decompression of the hematoma without any delay. Moreover, external incisions (lateral canthotomy or inferior cantholysis) can be done if necessary, for decompression and in order to release the hematoma (Brucoli et al., 2012).

Mandibular angle fractures

Introduction

Mandibular angle fractures are among the most common injuries of the maxillofacial region and can be treated in various ways. Therefore, no general agreement is observed in the literature, regarding the optimal treatment of this facial fracture.

Many factors are responsible for the high reported rates of postoperative complications, such as facial nerve injury (marginal mandibular branch) (104).

When using a traditional intraoral approach, it may be difficult to correctly place a fixation plate because of limited access and visualization. This intraoperative problem can be resolved with the usage of an endoscope.

Benefits of using the endoscope

A surgeon can use a superior and inferior border plate with great precision. The ability to view the entire fracture line up to the inferior border of the mandible gives the opportunity for anatomic bone reduction. Furthermore, the use of an endoscope eliminates the hazard of facial nerve injury or other neurovascular complications, such as bleeding. Another important benefit is that it allows the patient to function immediately rather than being in stress and suffer from closed reduction technique (IMF).

The use of an endoscope, in comparison with the extraoral Open Reduction–Internal Fixation (ORIF) technique, has less pain and postoperative edema and the scar is much less visible 6. Last but not least, excellent functional results 12 weeks post-operatively are obtained (bite, normal occlusion, mouth opening) (105).

Subcondylar Fractures

Introduction

Many approaches for the management of mandibular condylar fractures are published in the literature and include functional (conservative treatment), closed reduction with IMF and ORIF (106). The incidence of this fracture ranges from 9 up to 45% of all mandibular fractures (107,108).
In the literature there is no agreement concerning the optimal management of subcondylar fractures, which supports either open or closed reduction techniques.
The use of an endoscope offers a third choice in the treatment of subcondylar fractures, with the advantages of the open technique (Table 6), but at the same time without the major disadvantages of the open technique (e.g. external visible scar, facial nerve branches injury, salivary fistula formation) (109-116).

Technique

The endoscopic-assisted technique for a subcondylar fracture can be carried out as an extraoral or atransoral procedure. Many authors suggest a transoral approach whenever possible in order to avoid the disadvantages of an extraoral incision. The extraoral endoscopic submandibular incision should be done only when the severity of the fracture abolishes the transoral approach as an obtainable technique (i.e. severe fracture override, severely oblique fracture or comminution) (118). Moderate to severe displacement segments, with considerable ramus height shortening, indicate the usage of the traditional external open technique.
Regarding the transoral approach, the mucosal incision is done at the pterygomandibular groove, on the anterior border of the ramus. The incision can be extended caudally to the vestibular mucosa corresponding to the mandibular first molar, similar to that of a sagittal split osteotomy (SSO) in orthognathic surgery.
Then, a subperiosteal dissection to the proximal mandibular part is done in order to create the working optical cavity. A 30º, 4 mm in diameter endoscope is most often used and advanced superiorly to the fracture area. Bear in mind that the subperiosteal dissection must uncover the lateral part of the mandibular ramus, the posterior border of the mandible, the sigmoid notch and the gonial angle. Afterwards, the inserted fibers of the temporalis muscle are stripped from the coronoid process. Then the endoscope is introduced on the lateral side of the ramus, with the help of a sigmoid notch retractor and a modified posterior border retractor, in order to observe and evaluate the fracture line.
The non-dislocated or laterally dislocated condylar segment can be reduced with instruments that each surgeon is comfortable with. Accurate anatomic reduction of the condylar section over the mandibular ramus is done with a long periosteal elevator and/or modified condylar distractors. After the reduction of the proximal segment, the elevator tip is placed on the lateral aspect of the fragment for temporary stabilization. A titanium specific miniplate for condylar fixation can be adapted over the condylar section and the ramus (Fig. 9).
The condylar segment is fixated with the use of one up to three titanium screws, via the transbuccal approach, after a small 3 mm skin incision in the tragal fold is performed, inferior to the lobe. In addition, note that the transbuccal trocar regime may result in damage of the branches of the facial nerve and blood vessels, infec-

Table 6: Advantages of Endoscopically assisted ORIF of subcondylar fractures over conventional ORIF (117)

Mostly performed with intraoral incisions
Improved vision and expanded field of operative view
Minor hemorrhage
Improved anatomic reduction
Decreased postoperative morbidity (i.e. pain, swelling, and limited mouth opening)
Immediate postoperative function of the mandible with TMJ function restored to unrestricted pre-trauma joint movement

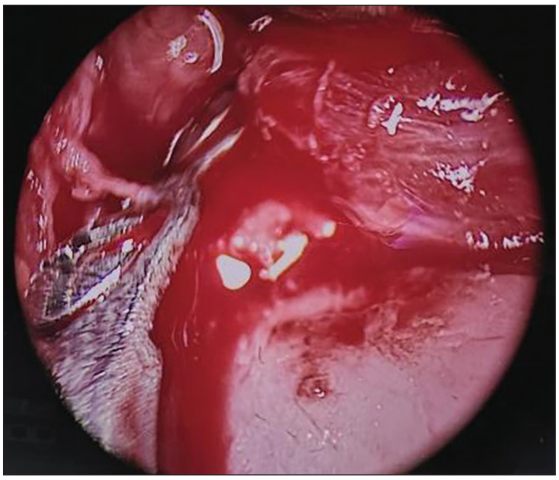

Fig. 9: A miniplate and screws placed at the posterior lateral surface of a subcondylar fracture

tion and sinus tract. The use of angled-type drills and screwdrivers decreases these complications. However the usage of these tools creates restrictions, such as the manipulation of instruments inside the closed optical cavity and the synchronization between the surgeon and his/her assistants. These restrictions are resolved with extensive training and experience (123, 124, 125).

Some authors agree and advance the use of a single mini-dynamic compression plate because as they say, it is the most reliable and stable in performance, although lately there is a scientific discussion about the general usage of compression plates in Maxillofacial Trauma. Alternatively, two miniplates, one alongside the lateral posterior border and one alongside the sigmoid notch (the line of tension) can be placed. A 3D-plate can also be used.

Upon completion of the procedure, the occlusion is always checked and the surgical wound is closed watertight.

An important surgical tip is that it is beneficial not to put the patient into Maxillomandibular Fixation (MMF), in order to permit movement between the proximal and distal segments. This allows for the bone reduction to be easily accomplished.

In cases of subcondylar fractures, in which the condyle segment is displaced but without dislocation, the fractures can be reduced and fixated via the intraoral approach aided by an endoscope. The subcondylar fractures with lateral override are easier to manage with an intraoral approach assisted with an endoscope in comparison with those of a medial override (119, 120, 121, 122). In subcondylar fractures with medial dislocation, endoscopic assisted reduction is very difficult to be achieved only with the intraoral approach. A combined intraoral and extraoral endoscopic approach is indicated in these situations. It is worth mentioning that an angulation of more than 45 degrees, between the fracture segments, especially those with simultaneous medial displacement, indicates the use of the traditional external open ORIF approach.

In cases where a combined intraoral and extraoral approach will be used, it is advisable to start with the intraoral endoscopic approach, complete the dissection and then perform the external endoscopic approach. This way, the facial nerve is safe and the skin scar is minimal (less than 1cm) (119). In rare occasions, where early malocclusion occurs, use an elastic IMF for 1 to 2 weeks in order to stabilize the correct occlusion.

The transoral endoscopic approach can be used for subcondylar fractures, whereas the extraoral endoscopic approach can be used for anything related to the Ramus Condylar Unit (RCU).

The extraoral endoscopic approach (submitted by Prof. Dr. M. Troulis) consists of a 1.5 cm subangulomandibular incision, approximately 2 cm cervical to the mandibular angle. Many procedures can be performed with this technique, such as condylectomy, costochondral grafts placement, coronoidectomy, Vertical Ramus Osteotomy (VRO) and fixation, biopsies and ORIF of subcondylar fractures.

Once the platysma muscle is passed, blunt dissection is performed towards the inferior border of the mandible and then a sharp incision is made through the pterygomasseteric sling using a number 15 size blade. The sharp dissection is continued down to the bone of the mandibular angle. Then a suction-assisted endoscopic elevator is placed (e.g. Snowden-Pencer elevators) in order to create an optical cavity.

The 30° endoscope should be placed parallel to the posterior border of the ramus with direct access to the condyle. The anterior and posterior borders of the ramus, the sigmoid notch, the coronoid process and the posterior body of the mandible are the visualized relevant anatomic landmarks.

A curved, long-handled retractor is placed in order to preserve the working optical cavity. Subsequently, an angle clamp is positioned at the angle to help with the distraction of the ramus. The distal and proximal pieces are recognized via the endoscope. Afterwards, a clamp is used for catching the condylar neck and for placing the condylar head in the fossa. Then, the fracture is reduced and the distracted ramus is set free.

A 2.0 mm (with 5 holes) titanium plate is positioned and the proximal screws are inserted. The plate-holder is then removed and the plate is used for handling the proximal segment. Reduction at the posterior border is checked and the distal screws are inserted, with or without the help of a percutaneous trocar.

Upon completion of the procedure, the incision is closed in layers using absorbable sutures for tissues under the skin and non-absorbable sutures for the skin.

Frontal sinus fracture (126, 127, 128, 129, 130)

Introduction

Frontal sinus fractures represent about 5-15 % of all facial bone fractures. One-third of them are isolated to the anterior table and this subtype of frontal sinus fractures is mainly a cosmetic defect. There are two basic endoscopic treatment choices for the anterior table frontal sinus fractures: endoscopic reduction and miniplate fixation or camouflage of the contour defect with the placement of an implant.

Be aware that frontal sinus fractures are usually linked with a remarkable force and they are involved with other intracranial or facial injuries, which definitely require neurosurgical consultation.

Traditional approaches that have been used until now for the treatment of those fractures include: Bicoronal, open-sky, gull-wing, butterfly, unilateral medial orbital incision or pre-existing lacerations. All these incisions allow the proper anatomic reduction and reconstruction under direct vision, but with many disadvantages such as facial scar, alopecia, bleeding, nerve injury etc.

Complex frontal sinus fractures should be managed with the above mentioned traditional open techniques. However, in an isolated anterior table fracture, with minimal displacement and without comminution, the endoscopic approach gives an alternative esthetic surgical option.

CONCLUSIONS

Surgeons have recently found many advantages from the use of an esdoscope in some oral & maxillofacial procedures. In the past, only traditional open (intraoral/extraoral) techniques were used. New appliances for endoscopically assisted procedures are being used and the benefits for the patients are notable. Reduced complication rates, high success rates, great postoperative functionality, early recovery, and improved esthetic results have made the endoscope a helpful tool in a maxillofacial surgeon's career.

As endoscopic surgery development progresses further, patients will benefit from shorter incisions, less pain and earlier recovery. And, evidently as surgeons become more familiar with the endoscopic techniques, more patients will benefit from minimally invasive surgery.

Among the advantages of MIS, it should be noted that it leads to less postoperative edema, quicker recovery, and less complications such as bleeding, nerve injury etc. Trauma, sialoendoscopy and TMJ surgery are procedures commonly executed with the help of an endoscope.

Finally, more clinical trials are needed in order to provide better based-evidence on some specific topics. Our main goal by writing this literature review article was to present a brief step-by-step explanation of the most frequently performed maxillofacial procedures that can be done with the aid of an endoscope, such as TMJ arthroscopy, Sialoendoscopy and Facial Trauma reconstruction. Nevertheless, taking the available literature evidence and discussion into consideration, it is concluded that the application of endoscopic techniques in the daily practice of oral and cranio-maxillofacial surgery is worthy, capable, effective and desirable.

Declaration
The authors have no declared financial interests.

REFERENCES

1. Frey M, editor. Endoscopy and Microsurgery. New York: Springer-Verlag Wien; 2001
2. Semm K. Atlas of Gynecologic Laparoscopy and Hysteroscopy. Philadelphia: WB Saunders; 1977
3. Tagaki K. Practical experience using Tagaki's arthroscope. Jpn J Orthop Assoc. 1933; 8:132
4. Tagaki K. The arthroscope. Jpn J Orthop Assoc. 1939; 14:359
5. Dallan, P. Castelnuovo, C. Vicini1, M. Tschabitsche, The natural evolution of endoscopic approaches in skull base surgery: robotic-assisted surgery
6. Pedroletti F, Johnson BS, McCain JP. Endoscopic techniques in oral and maxillofacial surgery. Oral Maxillofac Surg Clin North Am. 2010; volume 22: pages 169–182
7. Kumar A, Yadav N, Singh S, Chauhan N. Minimally invasive (endoscopic-computer assisted) surgery: Technique and review. Ann Maxillofac Surg 2016; 6:159-64
8. Four hands technique in transoral endoscope-assisted fixation of condyle fractures. Gokcan MK, Kucuk B, Yazicioglu D, Tuzuner Oncul A J Otolaryngol Head Neck Surg. 2010 Aug; 39(4):442-7
9. Miloro M. Endoscopic-assisted repair of subcondylar fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96(4):387–91
10. Ohnishi M. Arthroscopy of the temporomandibular joint. J Stomatol Soc Jpn 1975; 42:207–13
11. Murakami KI, Ito K. Arthroscopy of the temporomandibular joint: arthroscopic anatomy and arthroscopic approaches in the human cadaver. Arthroscopy 1981; 6:1–13
12. Murakami KI, Hoshino K. Regional anatomical nomenclature and arthroscopic terminology in human temporomandibular joints. Okajamas Folia Anat 1982; 58:745–60
13. Murakami KI, Hoshino K. Histological studies on the inner surfaces of the articular cavities of human temporomandibular joints with special reference to arthroscopic observations. Anat Anz 1985; 160:167–77
14. Nuelle D, Alpern MG, Ufema JW. Arthroscopic surgery of the temporomandibular joint. Angle Orthodontist 1986; 56:118–20
15. McCain JP, DeLaRua H, LeBlanc N. Puncture technique and portals of entry for diagnostic and operative arthroscopy of the TMJ. Arthroscopy 1991;7(2):221–32
16. McCain JP, Williams L. Principles and practice of temporomandibular joint arthroscopy. St Louis: Mosby; 1996. p. 1–11
17. Sanders B. Arthroscopic surgery of the temporomandibular joint: treatment of internal derangement with persistent closed lock. Oral Surg Oral Med Oral Pathol 1986; 02:361
18. Bhagwat H, Sheikh S, Wadhwania A, Patil N, Ahmed Z. Endoscopy in Oral and Maxillofacial Surgery. Int J Oral Health Med Res 2015;2(4):98-101
19. Franklin M. Dolwick, ... Shahrokh C. Bagheri, in Current Therapy In Oral and Maxillofacial Surgery, 2012 Diagnosis and Management of Temporomandibular Joint Pain and Masticatory Dysfunction
20. R. Dean White, Arthroscopy of the temporomandibular joint: technique and operative images. Atlas Oral Maxillofacial Surg Clin N Am 11 (2003) 129–144
21. Andrew Sidebottom, KenIchiro Murakami, in Maxillofacial Surgery (Third Edition), 2017 Arthrocentesis and Arthroscopic Management of the Temporomandibular Joint
22. Regional Arthroscopy book - Vaibhav Bagaria. 27 Feb 2013
23. Modern Arthroscopy - Jason L. Dragoo. 9 Dec 2011
24. Shelly Abramowicz, Joshua M Levy, Sampath Prahalad, Curtis D Travers, Sheila T Angeles-Han: Temporomandibular joint involvement in children with juvenile idiopathic arthritis: a preliminary report Oral Surg Oral Med Oral Pathol Oral Radiol. 2019 Jan;127(1):19-23

25. Daniel E Torres, Joseph P McCain: Arthroscopic electrothermal capsulorrhaphy for the treatment of recurrent temporomandibular joint dislocation Int J Oral Maxillofac Surg 2012 Jun;41(6):681-9
26. Wilkes C. Internal derangements of the temporomandibular joints. Arch Otolaryngol Head Neck Surg 1989;115(4):469–77
27. Peterson's Principles of Oral and Maxillofacial Surgery third edition
28. Deepak Kademani, Paul Tiwana - Atlas of Oral and Maxillofacial Surgery. Chapter 123. Elsevier Health Sciences, 9 Apr 2015 – Medical
29. Edvitar Leibur., et al. "Current Concepts in the Surgical Management for Temporomandibular Joint Osteoarthritis". EC Orthopaedics 12.6 (2021): 60-66. Current Concepts in the Surgical Management for Temporomandibular Joint Osteoarthritis
30. Temporomandibular joint arthrocentesis for the treatment of osteoarthritis - Temporomandibular Joint Arthroscopy Edvitar Leibur, Oksana Jagur and Ülle Voog-Oras. Stomatologija 2015; 17 (4): 113-17
31. Advanced Arthroscopy of the Temporomandibular Joint Joseph P. McCain DMD and Reem H. Hossameldin DMD Atlas of the Oral and Maxillofacial Surgery Clinics of North America, 2011-09-01, Volume 19, Issue 2, Pages 145-167, Copyright © 2011 Elsevier Inc
32. Arthroscopy of the temporomandibular joint: technique and operative images. R. Dean White, DDS, MS. Atlas of the Oral & Maxillofacial surgery clinics - VOLUME 11, ISSUE 2, P129-144, SEPTEMBER 01, 2003
33. Franklin M. Dolwick, ... Shahrokh C. Bagheri, in Current Therapy In Oral and Maxillofacial Surgery, 2012 Diagnosis and Management of Temporomandibular Joint Pain and Masticatory Dysfunction
34. McCain et al. 1992; Murakami et al. 1998b, 2000; Reston and Turkelson 2003; Hall et al. 2005; Smolka and Iizuka 2005; Schiffman et al. 2007 Temporomandibular Joint Arthroscopy
35. Franklin M. Dolwick, ... Shahrokh C. Bagheri, in Current Therapy In Oral and Maxillofacial Surgery, 2012 Diagnosis and Management of Temporomandibular Joint Pain and Masticatory Dysfunction
36. Gonzales-Garcia R, Rodriguez-Campo FJ. Complications of temporomandibular joint arthroscopy: a retrospective analytic study of 670 arthroscopic procedures. J Oral Maxillofac Surg 2006; 64:1587
37. Wilk BR, McCain JP. Rehabilitation of the TMJ after arthroscopic surgery. Oral Surg Oral Med Oral Pathol 1992;73(5):531–6
38. Hendler BH, Levin LM. Post obstructive pulmonary edema as a sequela of temporomandibular joint arthroscopy: a case report. J Oral Maxillofac Surg 1993;51(3):315–7
39. Westesson P, Eriksson L, Liedberg J. The risk of damage to the facial nerve, superficial temporal vessels, disk, and articular surfaces during arthroscopic examination of the temporomandibular joint. Oral Surg Oral Med Oral Pathol 1986; 62:124–7
40. Koslin M. Advanced arthroscopic surgery. Oral Maxillofac Surg Clin North Am 2006; 18:329–4
41. Deepak Kademani, Paul Tiwana - Atlas of Oral and Maxillofacial Surgery. Chapter 123. Elsevier Health Sciences, 9 Apr 2015 - Medical
42. M. Anthony Pogrel, in Complications in Head and Neck Surgery (Second Edition), 2009 Temporomandibular Joint Surgery
43. McCain JP, DeLaRua H, LeBlanc N. Puncture technique and portals of entry for diagnostic and operative arthroscopy of the TMJ. Arthroscopy 1991;7(2):221–32
44. McCain JP, Williams L. Principles and practice of temporomandibular joint arthroscopy. St Louis: Mosby; 1996. p. 1–11
45. Iro H, Zenk J, Koch M, et al. The Erlangen salivary gland project; 2007. p. 12–3
46. Katz P. Nouvelle therapeutique des lithiases salivaire [New therapy for sialolithiasis]. Inf Dent 1991;73: 3975–9 [in French]
47. Nahlieli O, Shacham R, Bar T, et al. Endoscopic mechanical retrieval of sialoliths. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003; 95:396–402
48. M. Papadaki, J. McCain, M. Troulis Published 2008 Medicine - Journal of oral and maxillofacial surgery: official journal of the American Association of Oral and Maxillofacial Surgeons - Interventional sialoendoscopy: early clinical results
49. Eisele D, Smith R. Complications of surgery of the salivary glands. Complications in head and neck surgery. 2nd edition. St Louis: Mosby; 2009. p. 221–39
50. Bailey BM, Pearce DE. Gustatory sweating following submandibular salivary gland removal. Br Dent J 1985; 158:17–8.
51. Nahlieli O. Endoscopic techniques for the diagnosis and treatment of salivary gland disease. Carl Stortz: Silver Books; 2009. p. 23
52. Nahlieli O., Neder A., and Baruchin A.M.: Salivary gland endoscopy: a new technique for diagnosis and treatment of sialolithiasis. J Oral Maxillofac Surg 1994; 52: pp. 1240-1242
53. Marchal F. The endoscopic approach to salivary gland ductal pathologies. Carl Stortz: Silver Books; 2005
54. Marchal F., Dulguerov P., and Lehmann W.: Interventional sialendoscopy. N Engl J Med 1999; 341: pp. 1242-1243
55. Michael D Turner, Surgical Armamentarium for Sialendoscopy. Atlas Oral Maxillofac Surg Clin North Am. 2018 Sep;26(2):85-91. doi: 10.1016/j.cxom.2018.05.001, PMID: 30077326
56. Nahlieli O, Eliav E, Hasson O, Zagury A, Baruchin AM. Pediatric sialolithiasis. Oral Surg Oral Med Oral Pathol 2000; 90:709–712
57. Minimally Invasive Endoscopic Oral and Maxillofacial Surgery Mohamed A Hakim 1, Joseph P McCain 1, David Y Ahn 2, Maria J Troulis - Oral Maxillofac Surg Clin North Am. 2019 Nov;31(4):561-567. Epub 2019 Aug 28 doi: 10.1016/j.coms.2019.07.001
58. Strychowsky J.E., Sommer D.D., Gupta M.K., et al.: Sialendoscopy for the management of obstructive salivary gland disease, a systematic review and meta-analysis. Arch Otolaryngol Head Neck Surg 2012; 138
59. Koch M, Zenk J, Bozzato A, et al. Sialoscopy in cases of unclear swelling of the major salivary glands. Otolaryngol Head Neck Surg 2005;133: 863–868
60. Miloro M. The surgical management of submandibular gland disease. Atlas Oral Maxillofac Surg Clin North Am 1998; 6:29–50
61. Geisthoff U. Basic sialendoscopy techniques. Otolaryngol Clin North Am 2009; 42:1029–1052
62. Marchal F. Sialolith management: the state of the art. Arch Otolaryngol Head Neck Surg 2003; 129:951–6
63. Marchal F, Kurt AM, Dulguerov P, et al. Histopathology of submandibular glands removed for sialolithiasis. Ann otol Rhinol Laryngol 2001; 110:464–9
64. Iro H, Schneider HT, Fodra C, et al. Shockwave lithotripsy of salivary gland duct stones. Lancet 1992; 339:1333
65. Marmary Y. A novel and non-invasive method for the removal of salivary gland stones. Int J Oral Maxillofac Surg 1992; 15:585
66. Iro H, Waitz G, Nitsche N, et al. Extracorporeal piezoelectric shock-wave lithotripsy of salivary gland stones. Laryngoscope 1992; 102:492
67. Hauser R, Vahlensieck W, Maier W, et al. Extracorporeal

piezoelectric lithotripsy in the treatment of a parotic calculus with recurrent parotiditis. Laryngorhinootologie 1990; 69:464.
68. Kater W, Hurst A, Schilck R, et al. Salivary gland stones: chances, risks and limits of ESWL. 10th World Congress on Endourology and ESWL 1992. Singapore 03-06
69. Arzoz E, Santiago A, Esnal F, et al. Endoscopic intracorporeal lithotripsy for sialolithiasis. J Oral Maxillofac Surg 1996; 54:847–50
70. Konigsberger R, Feyh j, Goetz A, et al. Die endoscopisch Kontrollierte Laser lithotripsy zur behandlung der sialolithiasis [Endoscopic controlled laser lithotripsy in the treatment of sialolithiasis]. Laryngorhinootologie 1990; 69:322 [in German
71. Arzoz E, Santiago A, Garatea J, et al. Removal of a stone with endoscopic laser lithotripsy: report of a case. J Oral Maxillofac Surg 1994; 52:1329
72. Leon Ardekian, Hila H. Klein, DMD, Sharif Araydy, DMD, Francis Marchal, MD, PhD - The Use of Sialendoscopy for the Treatment of Multiple Salivary Gland Stones. PATHOLOGY| VOLUME 72, ISSUE 1, P89-95, JANUARY 01, 2014
73. David E. Eibling, Transoral Removal of Salivary Duct Calculi in Operative Otolaryngology: Head and Neck Surgery (Second Edition), 2008
74. Zenk J, Zikarsky B, Hosemann WG, et al. The diameter of the Stensen and Wharton ducts. Significance for diagnosis and therapy [in German]. HNO 1998; 46:980–985
75. Luers J, Vent J, Beutner D. Methylene blue for easy and safe detection of salivary duct papilla in sialoendoscopy. Otolaryngol Head Neck Surg 2008;139: 466–7
76. Kevin Oshiro Do, M. Boyd Gillespie, in Surgery of the Salivary Glands, 2021 - Sialendoscopy for Stenosis
77. Chossegros C, Guyot L, Richard O, et al. A technical improvement in sialendoscopy to enter the salivary ducts. Laryngoscope 2006;116: 842–844
78. Nahlieli O, Baruchin A. Endoscopic technique for the diagnosis and treatment of obstructive salivary gland disease. J Oral Maxillofac Surg 1999;57: 1394–401
79. Mark McGurk MD, FRCS, FDSRCS, DLO, Jackie Brown BDS, MSc, FDSRCPS, DDRRCR, in Otolaryngologic Clinics of North America, 2009 - Sialendoscopy and Lithotripsy
80. Endoscopic treatment of salivary glands affected by autoimmune diseases. Rachel Shacham, Max B Puterman, Nili Ohana, Oded Nahlieli - J Oral Maxillofac Surg. 2011 Feb;69(2):476-81. doi: 10.1016/j.joms.2010.10.002. Epub 2010 Dec 8.
81. McGurk M. Minimal invasive methods and procedures for the treatment of salivary gland sialolithiasis. In: Nahlieli O, Iro H, McGurk M, Zenk J. Herzelia, eds. Modern Management Preserving the Salivary Glands. Herzliya, Israel: Isradon Ltd.; 2007:136–174
82. Koch M, Zenk J, Iro H. Algorithms for treatment of salivary gland obstructions. Otolaryngol Clin North Am 2009; 42:1173–1192.
83. Nahlieli O, Shacham R, Bar T, et al. Endoscopic mechanical retrieval of sialoliths. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;95: 396–402
84. Walvekar RR, Razfar A, Carrau RL, Schaitkin B. Sialendoscopy and associated complications: a preliminary experience. Laryngoscope 2008;118: 776–779
85. Nahlieli O. Classic approaches to sialoendoscopy for treatment of sialolithiasis. In: Witt RL, ed. Salivary Gland Diseases. New York, NY: Thieme Medical Publishers; 2006:79–93
86. Geisthoff, Maune S. Ultrasound-guided surgical fragmentation of sialoliths (sonoguide forceps). Head Neck 2010; 32:1641–1647.
87. Nahlieli O, Shacham R, Zagury A, et al. The ductal stretching technique: an endoscopic-assisted technique for removal of submandibular stones. Laryngoscope 2007; 117:1031–1035
88. McGurk M. Minimal invasive methods and procedures for the treatment of salivary gland sialolithiasis. In: Nahlieli O, Iro H, McGurk M, Zenk J. Herzelia, eds. Modern Management Preserving the Salivary Glands. Herzliya, Israel: Isradon Ltd.; 2007:136–174
89. Zenk J, Constantinidis J, Al-Kadah B, Iro H. Transoral removal of submandibular stones. Arch Otolaryngol Head Neck Surg 2001;127: 432–436
90. Marchall F. Removal of calculi or strictures in salivary ducts that cannot be removed by sialendoscopy. In: Myers EN, Ferris RL, eds. Salivary Gland Disorders. Heidelburg, Germany: Springer; 2007:149–158
91. Walvekar RR, Tyler PD, Tammareddi N, Peters G. Robotic-assisted transoral removal of a submandibular megalith. Laryngoscope 2011;121: 534–537
92. McGurk M, MacBean A, Fan KF, Sproat C. Conservative management of salivary stones and benign parotid tumours: a description of the surgical techniques. Ann R Australas Coll Dent Surg 2004; 17:41–44
93. Nahlieli O, Baruchin AM. Long term experience with endoscopic diagnosis and treatment of salivary gland inflammatory diseases. Laryngoscope 2000; 110:988–93
94. ENT surgery-current scope, problems and perspective. S.C. Sharma, ... Prem Sagar, in Trends in Anaesthesia and Critical Care, 2011
95. Complications of sialendoscopy: personal experience, literature analysis, and suggestions, Oded Nahlieli - J Oral Maxillofac Surg. 2015 Jan;73(1):75-80. doi: 10.1016/j.joms.2014.07.028. Epub 2014 Jul 30
96. Wallace TD, Moore CC, Bromwich MA, et al. Endoscopic repair of orbital floor fractures: computed tomographic analysis using a cadaveric model. J Otolaryngol 2006;35(1):1–7
97. Saunders CJ, Whetzel TP, Stokes RB, et al. Transantral endoscopic orbital floor exploration: a cadaver and clinical study. Plast Reconstr Surg 1997; 100(3):575–81
98. Strong EB. Endoscopic repair of orbital blow-out fractures. Facial Plast Surg 2004;20(3):223–30
99. Deepak Kademani, Paul Tiwana · 2015 · Medical - Atlas of Oral and Maxillofacial Surgery page 774 (part VI)
100. Jin HR, Yeon JY, Shin SO, et al. Endoscopic versus external repair of orbital blowout fractures. Otolaryngol Head Neck Surg 2007;136(1):38–44
101. Ellis E. Management of fractures through the angle of the mandible. Oral Maxillofac Surg Clin North Am 2009;21(2):163–74
102. Biomaterials for Repair of Orbital Floor Blowout Fractures: A Systematic Review. Dharmindra Rajah Gunarajah DDS, MDS* Nabil Samman FRCS, FDSRCS. Journal of Oral and Maxillofacial Surgery, Volume 71, Issue 6, June 2013, Pages 1151-1154
103. The evolution of craniofacial resection: A new workflow for virtual planning in complex craniofacial procedures. Alessandro Tel, Daniele Bagatto, Francesco Tuniz, Salvatore Sembronio, Fabio Costa, Serena D'Agostiniand Massimo Robiony. Journal of Cranio-Maxillo-Facial Surgery, 2019-09-01, Volume 47, Issue 9, Pages 1475-1483, Copyright © 2019 European Association for Cranio-Maxillo-Facial Surgery
104. Walker RV. Traumatic mandibular condyle fracture dislocation: effect of growth in the Macaca monkey. Am J Surg 1960; 100:850
105. A Study on Endoscopic Assisted Reduction And Fixation of Fracture Angle of Mandible Dr. Jacob Antony 1, Dr. Manish Tailor2, Dr. Digvijay Singh Rawat3, Dr. Yogesh Aseri4, Dr. B. K Singh5, Dr.P. C Verma. IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)- e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 16, Issue 6 Ver. VIII (June. 2017), PP 32-36

106. How far we have come with the Management of Condylar Fractures? A Meta-Analysis of Closed Versus Open Versus Endoscopic Management. Rathindra Nath Bera, Janani Anand Kumar, Shweta Kanojia, Fargol Mashhadi Akbar Boojar, Nishtha Chauhan & Mehul Shashikant Hirani - Published: 28 May 2021- Journal of Maxillofacial and Oral Surgery (2021)
107. Brandt MT, Haug RH. Open versus closed reduction of adult mandibular condyle fractures: a review of the literature regarding the evolution of current thoughts on management. J Oral Maxillofac Surg 2003; 61:1324
108. Schon R, Roveda SI, Carter B. Mandibular fractures in Townsville, Australia: incidence, aetiology and treatment using the 2.0 AO/ASIF miniplate system. Br J Oral Maxillofac Surg 2001; 39:145
109. Walker RV. Condylar fractures: nonsurgical treatment. J Oral Maxillofac Surg 1994; 52:1185
110. Baker AW, McMahon J, Moos KF. Current consensus on the management of fractures of the mandibular condyle. Int J Oral Maxillofac Surg 1998; 27:258
111. Ellis E III, Simon P, Throckmorton GS. Occlusal results after open or closed treatment of fractures of the mandibular condylar process. J Oral Maxillofac Surg 2000; 58:260.
112. Haug RH, Assael LA. Outcomes of open versus closed treatment of mandibular subcondylar fractures. J Oral Maxillofac Surg 2001; 59:370.
113. Sorel B. Management of condylar fractures. Oral Maxillofac Surg Knowledge Update 2001; 3:47
114. Assael LA. Open versus closed reduction of adult mandibular condyle fractures: an alternative interpretation of the evidence. J Oral Maxillofac Surg 2003; 61:1333
115. Walker RV. Management of subcondylar fractures. Presented at the 86th annual meeting of the Association of Oral and Maxillofacial Surgery 2003. Orlando (FL), September
116. Ellis E III, Moos KF, el Attar A. Ten years of mandibular fractures: an analysis of 2,137 cases. Oral Surg Oral Med Oral Pathol 1985; 59:120
117. Miloro M. Endoscopic-assisted repair of subcondylar fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96(4):387–91
118. Schon R, Gutwald R, Schramm A, et al. Endoscopy assisted open treatment of condylar fractures of the mandible: extraoral vs intraoral approach. Int J Oral Maxillofac Surg 2002; 31:237
119. Minimizing the Submandibular Incision in Endoscopic Subcondylar Fracture Repair. Yasser Abdallah Aboelatta, MD, Amir S. Elbarbary, MD, Sarah Abdelazeem, MSc, Karim S. Massoud, MD, Ikram I. Safe, MD Department of Plastic & Reconstructive Surgery, Ain-Shams University, Cairo, Egypt- First Published December 1, 2015
120. Venkatesh Anehosur, MDS, Abhijit Joshi, MDS, and Saravanan Rajendiran, MDS. Endoscopic-Assisted Intraoral Open Reduction Internal Fixation of Mandibular Subcondylar Fractures: Initial Experiences from a Tertiary-Care Maxillofacial Center in India. Craniomaxillofac Trauma Reconstr. 2018 Sep; 11(3): 183–191. Published online 2017 Jun 12
121. Endoscopic approach to the ramus/condyle unit: Clinical applications. Troulis MJ, Kaban LB J Oral Maxillofac Surg. 2001 May; 59(5):503-9
122. Review Management of subcondylar mandible fractures in the adult patient. Hackenberg B, Lee C, Caterson EJ J Craniofac Surg. 2014 Jan; 25(1):166-71
123. Five-year experience with the transoral endoscopically assisted treatment of displaced condylar mandible fractures. Schön R, Fakler O, Gellrich NC, Schmelzeisen R Plast Reconstr Surg. 2005 Jul; 116(1):44-50
124. Long-term outcomes after treatment of condylar fracture by intraoral access: a functional and radiologic assessment. Veras RB, Kriwalsky MS, Eckert AW, Schubert J, Maurer P J Oral Maxillofac Surg. 2007 Aug; 65(8):1470-6
125. Endoscopically assisted reduction and fixation of condylar neck/base fractures--The learning curve. Loukota RA Br J Oral Maxillofac Surg. 2006 Dec; 44(6):480-1
126. Cole P, Kaufman Y, Momoh A, et al. Techniques in frontal sinus fracture repair. Plast Reconstr Surg 2009;123(5):1578–9
127. Hewitt DK, Scheidt TD, Calhoun KH. Depressed anterior table fracture: a minimally invasive method of reduction. Ear Nose Throat J 2009; 88(1):734–5
128. Chen DJ, Chen CT, Chen YR, et al. Endoscopically assisted repair of frontal sinus fracture. J Trauma 2003;55(2):378–82
129. Steiger JD, Chiu AG, Francis DO, et al. Endoscopic-assisted reduction of anterior table frontal sinus fractures. Laryngoscope 2006;116(10):1936–9
130. Yoo MH, Kim JS, Song HM, et al. Endoscopic trans-nasal reduction of an anterior table frontal sinus fracture: technical note. Int J Oral Maxillofac Surg 2008; 37(6):573–5
131. Schubert W, Jenabzadeh K. Endoscopic approach to maxillofacial trauma. J Craniofac Surg 2009; 20(1):154–6
132. Mueller R. Endoscopic treatment of facial fractures. Facial Plast Surg 2008;24(1):78–91
133. Strong EB, Kellman RM. Endoscopic repair of anterior table–frontal sinus fractures. Facial Plast Surg Clin North Am 2006;14(1):25–9

Adress:
Dr. Nicolaou Zoe
3 Dimitri Liperti Street, Cotsapa Court A. Office 302
3090 Limassol, Cyprus
Tel: +357 2576 1010
e-mail: info@ccmfc.com.cy