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Temporomandibular Joint Morphology Changes with Mandibular Advancement Surgery and Rigid Internal Fixation: A Systematic Literature Review

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ABSTRACT

The purpose of this systematic review was to evaluate the effect of bilateral sagittal split mandibular osteotomy (BSSO) with rigid internal fixation (RIF) on temporomandibular joint (TMJ) morphology. Controlled trials of BSSO with RIF treatment of Class II patients using transcranial radiographs, submental vertex (SMV) radiographs, tomographic radiography, computed tomography (CT) scan, or magnetic resonance imaging (MRI) to assess TMJ morphology were identified by Medline (1966–2001) and PubMed. Case reports were excluded. On the basis of our search only six studies were included in this review. All studies used internal controls with pre- and posttreatment imaging. Two studies used SMV, one used transcranial radiographs, one used tomography, two used CT scan and one used MRI. Methodological deficiencies prevent major conclusions regarding osseous remodeling and disk status. There was a wide range of individual variability in condyle position change. The reviewed studies have highlighted the importance of further research. Prospective controlled studies using serial MRI and tomography or CT scan are required to establish effect of BSSO with RIF on TMJ morphology.

KEY WORDS: Bone screws, Diagnostic imaging, Mandibular condyle, Bilateral sagittal split osteotomy (BSSO), Temporomandibular joint disorders.

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INTRODUCTION Return to TOC

Orthognathic surgery is an important treatment method for patients with significant skeletal dysplasias. For patients who choose orthognathic surgery to correct their skeletal problems involving the mandible, the most common approach to treatment today is the bilateral sagittal split osteotomy (BSSO) and rigid internal fixation (RIF).[1]

In the past, the majority of orthognathic surgical procedures used wire fixation to stabilize segments at the time of surgery. This was followed with approximately six weeks of intermaxillary fixation while the bony segments healed. Although this produced satisfactory results, the flexibility between segments with wire fixation allowed for some movement of the segments that contributed to increased relapse. Stability has been enhanced with the introduction of RIF.[2]

The effect of RIF on the temporomandibular joint (TMJ) is an area of concern. A common concern is that rigid fixation may torque the condyles relative to the glenoid fossa, unlike wire fixation that appears less rigid. Alteration of TMJ morphology may adversely affect function leading to temporomandibular disorders (TMD). Furthermore, secondary osseous remodeling in the TMJ may lead to decreased stability of the surgical result.

The purpose of this review was to evaluate the effect of BSSO mandibular advancement surgery with RIF on TMJ morphology. The specific research questions were:

1. What are the effects on TMJ osseous morphology?
2. What are the effects on disk position?
3. What are the effects on condylar position in all planes of space?

METHODS Return to TOC

The following criteria were used to consider studies for this review:

1. Adult patients (male or female) treated with BSSO mandibular advancement surgery and RIF (screws or plates).
2. Utilization of transcranial radiographs, submental vertex (SMV) radiographs, tomographic radiography, computed tomography (CT) scan, or magnetic resonance imaging (MRI) to view the TMJ.
3. Controlled study (minimum internal control with pre- and postintervention imaging).
4. Case reports were excluded.

To identify the relevant articles for this systematic review, a search was conducted for Medline (1966 to October 2001). PubMED was also searched with the keywords and subjects used for Medline in an attempt to locate more recent publications that may have been omitted with Medline. None were found. The researcher reviewed the abstracts of related articles and hand searched the reference list of articles that met the inclusion criteria. The search strategy used for this study is shown in Table 1.

Reading the abstracts eliminated many articles but others required a full read of the methods section. Two of the authors read all eligible reports, and agreement of inclusion was reached by discussion.

RESULTS Return to TOC

Eight articles that met the inclusion criteria were identified. The study by Spitzer et al[3] was eliminated because of unclear methodology even though it met all the inclusion criteria. The study by Harris et al[4] used the same sample and same imaging as Alder et al[5] and was eliminated. The remaining six articles are summarized in Table 2 and were published between 1989 and 1999. All the six articles had different primary authors but there was some overlap in the group with second and third authors.

The type of diagnostic imaging used varied significantly. Only SMV radiographs were used in more than one of the studies. Two different forms of CT were used (3D CT and linear CT).

There were no random clinical trials and no multicenter studies in the sample. One study took records at three points in time but the remaining studies had two sets of records. The timing of data collection varied widely between studies. Only one study took records more than 6–12 months after surgery.

The statistics used were primarily *t*-tests to compare groups and some multiple regression analyses to look at contributing factors such as the amount of advancement. Some studies had limited statistical analysis and displayed descriptive statistics only.

This study was intended to answer three questions. Each question addressed a possible or perceived problem that could occur after orthognathic surgery to advance the mandible. Data relevant to each question will be presented separately.

What are the effects on the hard tissues of the joint?

Schultes et al[6] used three-dimensional CT (3D CT) to create milled polyurethane models of mandibles before and six weeks after surgery. Condyle dimensions were measured directly on the models using calipers. They reported no changes in condylar width or height measurements. Method error was not provided, and there was no statistical analysis. The primary contribution of this article was their use of

CT generated models to assess morphologic change.

Gaggl et al[7] used pre- and postoperative MRI to analyze joints in 25 patients. They found that the number of joints exhibiting osseous degenerative changes increased from 7/50 to 9/50 at three months after surgery. This was not significant but hints at possible problems. The methods in this study were not well described, and it was not clear how they analyzed the joints and who analyzed the joints. There was no record of blinding, and method error was not reported.

What are the effects on the disk?

Gaggl et al[7] completed both static and dynamic MRI examinations in 25 patients. Seven of the 25 patients had maxillary surgery with mandibular advancements but these patients were not separated in the results section. There was no indication of how the patients were selected and whether they were consecutively treated. No information was given on MRI assessment technique. Disk position and disk degeneration was based on subjective assessment. No report of how partial displacements were categorized was provided. No definition of disk degeneration was given, but 54% of joints were reported to have preoperative disk displacement and 44% were reported to have disk degeneration. There was no record of blinding, number of examiners, or method error. The authors reported reduced number of joints with disk displacement (not statistically significant) but no change in the number of joints with disk degeneration.

What are the effects on the condyle in all planes of space? (sagittal, transverse, vertical)

Rotskoff et al[8] compared BSSO and RIF cases treated with and without a condyle proximal segment-positioning device (CPD) used at the time of surgery. Other than this device, patients were treated in the same manner. A total of 20 patients were treated and analyzed with axially corrected sagittal tomography. Acetate tracings of the TMJs taken preoperatively and one day postoperatively, were superimposed using the squamotympanic fissure, glenoid fossa, articular eminence, and posterior aspect of the condyle and ramus as constant anatomic landmarks. Vertical displacement was measured by direct measurement of superior joint space. Horizontal condylar position and rotation were based on displacement from pretreatment position. There were no reports of examiner blinding and method error. They reported that on average condyles were displaced posteriorly, inferiorly with forward rotation of the condyle. Displacement was less pronounced in the group where the CPD was used. Mean condyle displacement was likely not clinically significant (0.37–0.83 mm) but the range was quite large (up to 3.6 mm)

Stroster et al[9] compared rigid fixation with wire fixation. They used transcranial radiography to look at condylar changes in the sagittal and vertical dimensions. They followed a method described by Pullinger and Hollender[10] to analyze condyle position by assessing anterior and posterior joint spaces. They reported inter- and intraoperator error for measurements taken from SMV, transcranial, and cephalometric radiographs (0.5 mm and 0.5°). Specific error values for individual measurements were not provided. They provided postsurgical changes and postorthodontic changes in their analysis. They found that there was a significant difference between the fixation types after surgery. Posterior joint space was decreased more with wire fixation. It is not clear whether the changes within the groups were significant, because these statistics were not provided. The average changes that occurred were very small with the majority of them being less than the standard deviation and method error. At the end of orthodontic treatment the two groups were no longer significantly different. These results are suggestive of a small average posterior displacement, which is likely not clinically significant. Transcranial radiography is useful in determining changes but is not necessarily the most valid or reliable technique for defining anatomically true condyle position within the fossa.[11] This is a significant weakness of this study where condyle/fossa relationship change is likely three-dimensional.

Alder et al[5] evaluated short-term changes in condylar position after BSSO and RIF. They looked at 21 consecutively treated patients and used CT as their investigation tool. Three investigators independently completed the appropriate measurements from two-dimensional images. Images were randomly measured with the investigators blinded. They had a well-described method to determine linear and angular changes, but method error was not provided. Descriptive statistics and *t*-tests were used to evaluate pre- and postsurgery (8 weeks) change in condyle position. They reported that all condyles had some displacement and that movement occurred in all directions. Data was presented as average displacements in the positive and negative direction. The proportion of patients with movement in a particular direction was also provided. The ranges were given as differences between the most positive and negative numbers. In the sagittal dimension, the majority of condyles moved posteriorly (67%) (mean = 1.6 mm, range = 2.8 mm), superiorly (60%) (mean = 1.2 mm, range = 2.5 mm), and demonstrated an inferior (distal rotation of the proximal segment) (61%) (mean = 8.6°, range = 15.6°). The remainder were displaced anteriorly to the same average distance, inferiorly to an average of 1.2 mm and rotated superiorly to an average of 3.2°. There was no statistically significant difference between the left and right sides. Statistical significance of the pre- and postsurgery condyle position changes was not provided.

Alder et al[5] also assessed intercondylar angulations. Condyles were analyzed independently for angular changes using a perpendicular line from the midline reference. The investigators found changes in all individuals at eight weeks. The problem was variability. There was a 60/40 split between increased and decreased condylar angles. The majority showed an increased angle, which would mean anterior movement of the medial and posterior movement of the lateral pole. This is the opposite of what other studies have shown and not what might be expected if the geometry of advancements is observed with rigid fixation. Their method may be partially responsible for this observation. The result might have been different if they used a reference plane that was fixed from T1 to T2. They also showed that more often than not the condyles moved laterally but this was by the slimmest of margins.

Hackney et al[12] used SMV films to assess intercondylar angles and intercondylar width. They measured the condyles in relation to each other. The radiographs for a sample of 15 patients were taken immediately before surgery and 6–12 months after surgery. One investigator completed all the tracings. Data was analyzed using *t*-tests and correlation coefficients. There was no report of blinding or method error. Hackney reported that there were no significant changes in mean intercondylar angle or intercondylar width regardless of the amount of advancement. There was a large range of intercondylar angle change (−12.6° to 20.75°) and intercondylar width change (−4.6 mm to 4.8 mm). Sample size was small in relation to the large range of change. There was no correlation between the magnitude of mandibular advancement and condylar position change in the transverse dimension. The time frame used in this study was appropriate to study intermediate term changes but should ideally have been more standardized. Also, it would have been interesting to see what difference there was immediately after surgery. The authors point out that changes did not support the geometric model for advancement that would produce increased changes with increased size of advancement. Their conclusions may be valid, but with the time frame used, some of the changes that may have occurred could have disappeared because of remodeling.

Stroster et al[9] also used SMV radiographs to assess changes in the transverse dimension. Their sample included 29 wire fixation patients and 24 RIF patients with imaging taken before surgery, approximately 30 days after surgery, and at completion of orthodontic treatment. Condylar angulation was measured for each condyle from a reference line (transspinosum axis). Method error was reported as 0.5°. There was no record of investigator blinding. They found that there was significantly more rotation of the condyles with rigid fixation (right mean = 5.7°, left mean = 5.3°) compared with wire fixation. This involved rotation of the medial aspect posteriorly and the lateral aspect anteriorly. This change was seen after surgery but not after orthodontics, which suggests that these changes do not last long term. This may be why no significant changes were seen in the Hackney et al[12] study. Within-group statistical analysis was not provided because this study focused on assessment of differences between wire fixation and RIF. This study hints that the condyles rotate inward with advancements and this makes sense geometrically. It also hints that these changes are within the ability of the TMJ to adapt and, over time, these changes may not be important.

Schultes et al[6] also analyzed changes in angulation. Their study used 3D models of the mandible constructed from 3D CT data. Their sample of 31 patients underwent mandibular advancement with a six-week period of intermaxillary wire fixation. They evaluated intercondylar angulation, which was defined by the intersection of the condylar axes, and intercondylar width, which was defined as the minimal distance between the medial poles. No error analysis was given, no record of investigator blinding was provided, and there was no discussion about who did the measurements. They summarized that the intercondylar angle was decreased by 2.5° on average, which would require rotation of the medial pole posteriorly and the lateral pole anteriorly. Intercondylar distance was increased by about two mm. No statistics were provided other than averages and standard deviations.

DISCUSSION Return to TOC

Randomized clinical trials are not feasible because of the nature of intervention. Internal controls comparing pretreatment (T1) and posttreatment (T2) diagnostic images are appropriate where examiner blinding is ensured and method error is clearly reported. This approach would be strengthened by introducing an additional imaging sequence (T0) taken a period of time before surgery that would be equivalent to the time interval T1 to T2. Error introduced by repeated imaging including patient positioning, tomographic and MRI slice depth, MRI slice orientation, and remodeling unrelated to surgery could be analyzed. Blinding is important in protecting against investigator bias.[13,14] To assess validity of reported results, method error must be reported. If method error exceeds the mean difference between comparison groups, no conclusion can be made.

Postsurgical TMJ remodeling and degenerative changes have been implicated in postsurgical relapse.[15,16] Arnett[2] discussed potential sources of relapse in BSSO mandibular advancement. He suggested that skeletal relapse could occur by osteotomy slippage, condylar sag, and condylar compression with morphologic change. Condylar sag relates to lack of seating of the condyle into the glenoid fossa at the time of surgery. Because the condyle “reseats” into its preoperative position within the glenoid fossa, the alveolar base of the mandible would rotate down and back. Condylar compression with secondary remodeling would be a source of relapse, 9–18 months after surgery. Compression could occur in medial, lateral, or posterior directions. Arnett et al[17,18] have also described idiopathic condylar resorption as a source of relapse evidenced by progressive mandibular retrusion. Some individuals may adapt to small joint changes whereas others may not. Whether or not adaptation occurs may be related to pretreatment TMJ disk status, the amount of change produced by surgery, the nature of the original malocclusion, or host remodeling capacity.[18,19]

Unfortunately, there is inadequate published information to establish the effect of BSSO with RIF on the osseous articular tissues within the TMJ. The Gaggl et al[7] article described degenerative changes but did not supply adequate information on methodology to be conclusive. Furthermore, there was no report of blinding or method error. The Schultes et al[6] article did not report method error or blinding.

The relative risk of developing TMJ internal derangement or inducing a progression of internal derangement with BSSO with RIF is an important issue in treatment planning and in obtaining informed consent. TMJ internal derangement is a common abnormality in the general population. Tallents et al[20] reported that 66% of their symptomatic sample and 33% of their asymptomatic volunteer sample had disk displacement. The prevalence of internal derangement in asymptomatic patients seeking orthodontic treatment may be even higher.[21] Clinical examination of disk status does not provide accurate determination of disk status and a definitive diagnosis requires MRI.[22] The etiology of disk displacement remains obscure, and the natural progression of internal derangement has not been well defined.[23,24] It is generally accepted that disk displacement with reduction precedes disk displacement without reduction. The time interval for progression is not well defined and risk factors in progression are also uncertain. The role of internal derangement in degenerative joint disease is uncertain[25] but disk abnormality may reduce the joint capacity to adapt to changes induced by condylar displacement associated with orthognathic surgery.

The only publication that evaluated disk position[7] was not conclusive. Methodology was not adequately described, there was no report of examiner blinding, and method error was not reported.

Condyle position changes within the glenoid fossa should be analyzed in three dimensions. This could be achieved using SMV radiographs with axially corrected sagittal and coronal tomography. Williamson et al[26] reported measurement error associated with several SMV analyses. Their findings highlight the relevance of individual variability and importance of reporting error. Change in condylar angulation is best reported in relation to stable landmarks rather than in relation to the other condyle. The Hackney et al[12] article did not report blinding or method error. The Stroster et al[9] article did report method error but there was no report of blinding and no statistical analysis of T1 to T2 change in condylar angulation with BSSO and RIF. The Rotskoff et al[8] article used axially corrected sagittal tomography but they did not report examiner blinding or method error.

The Alder et al[5] study had sound well-described methodology. Although method error was not provided it is fair to conclude that all the condyles had some 3D displacement. The magnitude and direction of displacement had large individual variability. The clinical significance of these displacements is unknown, and no long-term studies to assess postsurgical remodeling have been published.

CT scan data provides a useful tool because displacement in three dimensions can be analyzed from a single imaging sequence. Acceptable accuracy of two-dimensionally reformatted CT images of the TMJ has been reported in other studies.[27,28] One cause for concern is the high dosage of radiation associated with CT scanning.[29] The value of the data set obtained for research vs the risk of the radiation dosage should be considered. This is particularly important in studies with repeated exposure. Accessibility and cost of CT scans may also be a consideration.

This systematic review has demonstrated the need for additional research to determine the effect of BSSO with RIF on TMJ morphology. Future research should include MRI assessment of disk position and disk morphology, radiographic assessment of osseous morphology, and 3D assessment of condyle position. To establish internal control and to evaluate method error, imaging should be assessed 6–8 weeks before surgery, immediately before surgery, and 6–8 weeks after surgery. To determine clinical relevance of changes induced by surgery long-term follow up imaging should also be acquired. The interrelationship between condyle position, disk status, and bony morphology should be explored using combined data obtained for a single sample. It may also prove useful to correlate cephalometric data with TMJ findings. Sample size can be estimated from the data of the existing studies.

CONCLUSIONS Return to TOC

The following conclusions regarding the effect of BSSO with RIF on TMJ morphology can be made.

1. The nature of condylar and glenoid fossa remodeling has not been established.
2. Changes in disk position and morphology have not been established.
3. Changes in condyle position present with large individual variability.

There is a need for research to determine the effect of BSSO with RIF on TMJ morphology. Future research requires effective use of controls, examiner blinding, and reporting of method error. The interrelationship between condyle position change, disk status, and osseous morphology need to be explored. It is important to establish the relative risk ratio of developing TMD, causing exacerbation, and/or progression of TMD. The long-term consequences of altered TMJ morphology and the relationship TMJ morphology to treatment stability should also be established.

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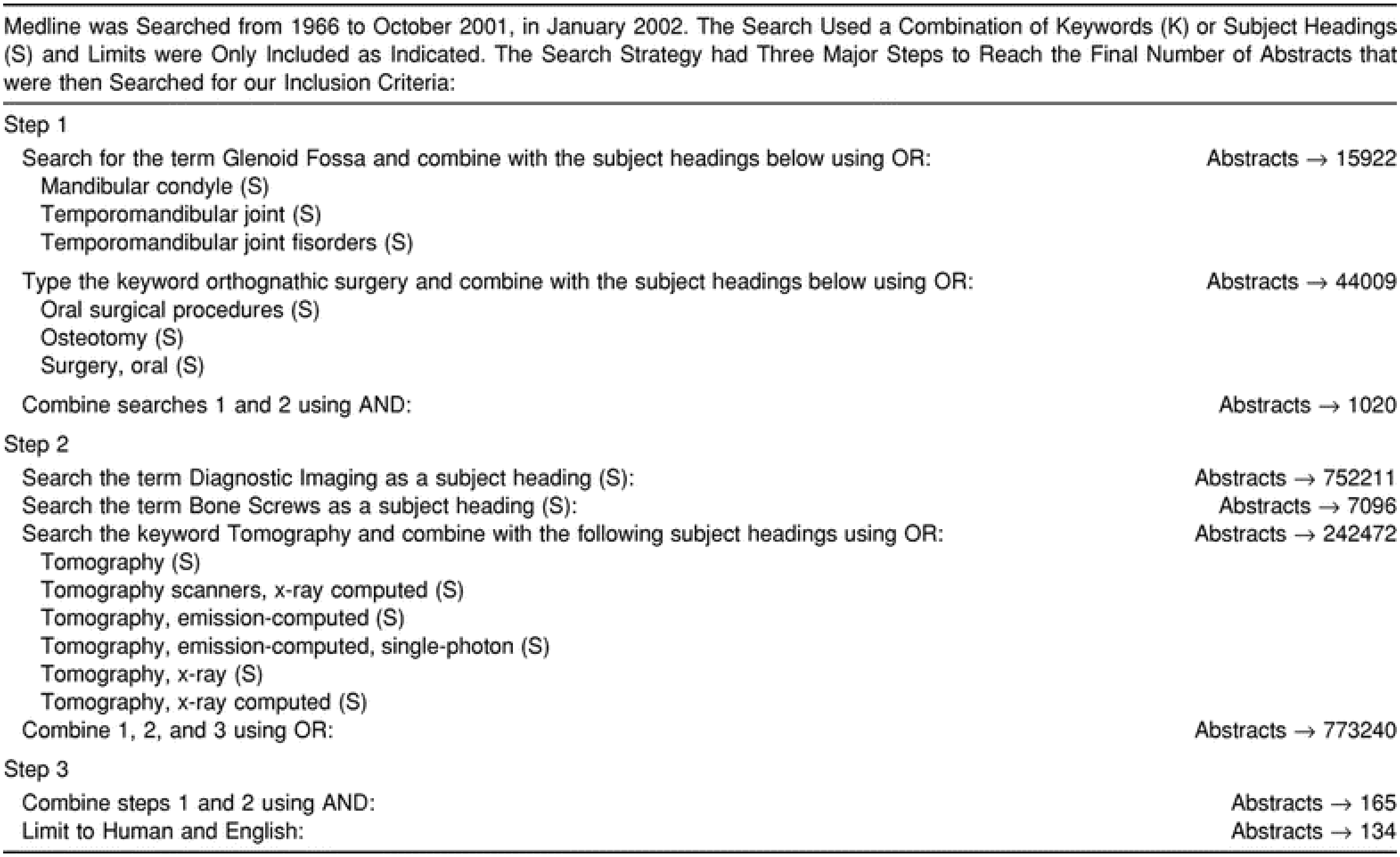
TABLES Return to TOC

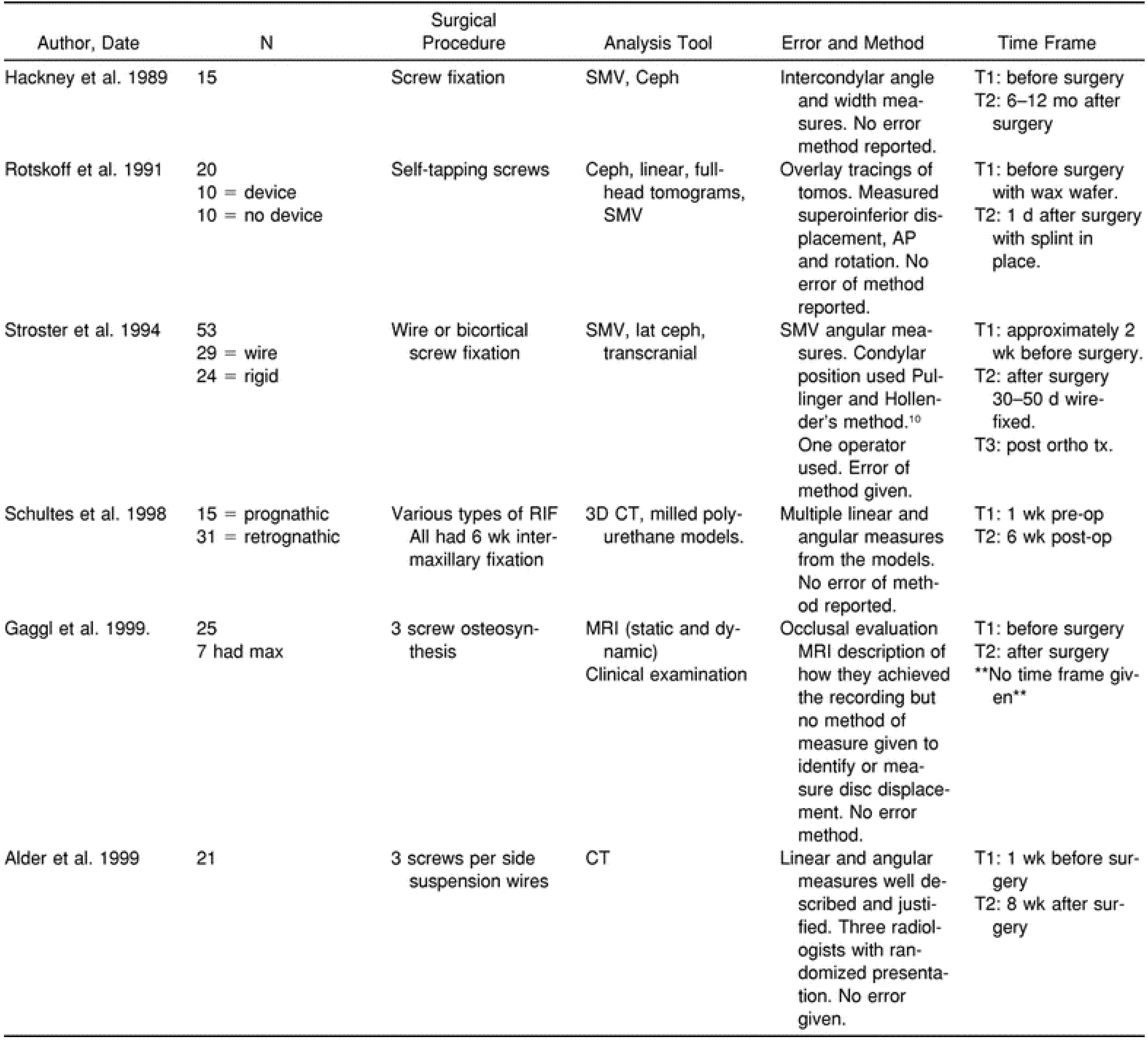
TABLE 1. Search Strategy



Medline was Searched from 1966 to October 2001, in January 2002. The Search Used a Combination of Keywords (K) or Subject Headings (S) and Limits were Only Included as Indicated. The Search Strategy had Three Major Steps to Reach the Final Number of Abstracts that were then Searched for our Inclusion Criteria:

Step 1	
Search for the term Glenoid Fossa and combine with the subject headings below using OR:	Abstracts → 15922
Mandibular condyle (S)	
Temporomandibular joint (S)	
Temporomandibular joint fisorders (S)	
Type the keyword orthognathic surgery and combine with the subject headings below using OR:	Abstracts → 44009
Oral surgical procedures (S)	
Osteotomy (S)	
Surgery, oral (S)	
Combine searches 1 and 2 using AND:	Abstracts → 1020
Step 2	
Search the term Diagnostic Imaging as a subject heading (S):	Abstracts → 752211
Search the term Bone Screws as a subject heading (S):	Abstracts → 7096
Search the keyword Tomography and combine with the following subject headings using OR:	Abstracts → 242472
Tomography (S)	
Tomography scanners, x-ray computed (S)	
Tomography, emission-computed (S)	
Tomography, emission-computed, single-photon (S)	
Tomography, x-ray (S)	
Tomography, x-ray computed (S)	
Combine 1, 2, and 3 using OR:	Abstracts → 773240
Step 3	
Combine steps 1 and 2 using AND:	Abstracts → 165
Limit to Human and English:	Abstracts → 134

TABLE 2. Studies Included for Review



Author, Date	N	Surgical Procedure	Analysis Tool	Error and Method	Time Frame
Hackney et al. 1989	15	Screw fixation	SMV, Ceph	Intercondylar angle and width measures. No error method reported.	T1: before surgery T2: 6–12 mo after surgery
Rotskoff et al. 1991	20 10 = device 10 = no device	Self-tapping screws	Ceph, linear, full-head tomograms, SMV	Overlay tracings of tomos. Measured superoinferior displacement, AP and rotation. No error of method reported.	T1: before surgery with wax wafer. T2: 1 d after surgery with splint in place.
Stroster et al. 1994	53 29 = wire 24 = rigid	Wire or bicortical screw fixation	SMV, lat ceph, transcranial	SMV angular measures. Condylar position used Pullinger and Hollender's method.[10] One operator used. Error of method given.	T1: approximately 2 wk before surgery. T2: after surgery 30–50 d wire-fixed. T3: post ortho tx.
Schultes et al. 1998	15 = prognathic 31 = retrognathic	Various types of RIF All had 6 wk intermaxillary fixation	3D CT, milled polyurethane models.	Multiple linear and angular measures from the models. No error of method reported.	T1: 1 wk pre-op T2: 6 wk post-op
Gaggl et al. 1999.	25 7 had max	3 screw osteosynthesis	MRI (static and dynamic) Clinical examination	Occlusal evaluation MRI description of how they achieved the recording but no method of measure given to identify or measure disc displacement. No error method.	T1: before surgery T2: after surgery **No time frame given**
Alder et al. 1999	21	3 screws per side suspension wires	CT	Linear and angular measures well described and justified. Three radiologists with randomized presentation. No error given.	T1: 1 wk before surgery T2: 8 wk after surgery

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