

# **CORRECTION OF DENTOFACIAL DEFORMITIES WITH ORTHOGNATHIC SURGERY**

Outcome of treatment with special reference to  
costs, benefits and risks

**KARI  
PANULA**

Department of Oral and  
Maxillofacial Surgery,  
Institute of Dentistry,  
University of Oulu

OULU 2003





*KARI PANULA*

**CORRECTION OF DENTOFACIAL  
DEFORMITIES WITH  
ORTHOGNATHIC SURGERY**

Outcome of treatment with special reference to  
costs, benefits and risks

Academic Dissertation to be presented with the assent of  
the Faculty of Medicine, University of Oulu, for public  
discussion in the Auditorium I of the Institute of  
Dentistry, on May 9th, 2003, at 12 noon.

OULUN YLIOPISTO, OULU 2003

Copyright © 2003  
University of Oulu, 2003

Reviewed by  
Docent Knut Tornes  
Docent Pekka Ylipaavalniemi

ISBN 951-42-6993-4 (URL: <http://herkules.oulu.fi/isbn9514269934/>)

ALSO AVAILABLE IN PRINTED FORMAT

Acta Univ. Oul. D 718, 2003

ISBN 951-42-6992-6

ISSN 0355-3221 (URL: <http://herkules.oulu.fi/issn03553221/>)

OULU UNIVERSITY PRESS

OULU 2003

**Panula, Kari, Correction of dentofacial deformities with orthognathic surgery.  
Outcome of treatment with special reference to costs, benefits and risks**

Department of Oral and Maxillofacial Surgery, Institute of Dentistry, University of Oulu, P.O.Box 5281, FIN-90014 University of Oulu, Finland

Oulu, Finland

2003

*Abstract*

Considerable amounts of research have been done on various aspects of orthognathic surgery during its short history. Nevertheless, there are no comprehensive publications on the cost-risk-benefit analysis of the entire process of orthognathic surgery. The purpose of the present study was to evaluate the psychosocial and biophysiological outcomes of orthognathic surgery with special reference to complications and financial costs.

The study series consisted of patients referred for consultations and treatment of dentofacial deformities and involved a total of 953 patients and 20 controls. Both prospective clinical follow-up examinations with measurements of various clinical parameters and retrospective assessments of radiographs and patient records were included.

Functional and pain-related reasons were found to motivate patients to seek orthognathic surgery, and this impression was confirmed by the clinical findings. The great majority of the subjects examined had signs and symptoms of temporomandibular disorders (TMD). The significance of facial appearance for the motivation to seek treatments seemed to play a lesser role compared to most earlier studies. Most of the patients felt that their expectations had been fulfilled by the treatment, and despite the potential risks involved, the overall complication rate in orthognathic surgery was very low. The most usual problem was neurosensory deficit of the inferior alveolar nerve.

TMD patients with skeletal Class II non-open bite dentofacial deformity seem to have the greatest probability to benefit from orthognathic surgery, especially if their TMD is mostly of muscular origin. Pain in the face and headache improved significantly. The outcomes were more variable when the TMD mainly originated from internal derangements. In these cases, the individual outcome of treatment is more difficult to predict, and conservative treatment methods should probably be tried first. The orthognathic surgery of patients with non-open bite skeletal Class II dentofacial deformity is also cost-effective due to the low complication rate and the low cost, since sagittal ramus osteotomy is often sufficient treatment. However, there must be weighty grounds for orthognathic surgery of skeletal open-bite deformities due to their greater risk for relapse and condylar resorption. The high expenses of their treatment also result in a poor cost-effectiveness ratio.

*Keywords:* benefit, cost, orthognathic surgery, risk



## Acknowledgements

This research was basically carried out at the Department of Oral and Maxillofacial Surgery, Vaasa Central Hospital, and at the Department of Oral and Maxillofacial Surgery, Institute of Dentistry, University of Oulu, during the years 1994–2003.

I owe my gratitude to several persons for support during these years, and I would especially like to mention some of them. I wish to express my greatest gratitude to my supervisor Professor Kyösti Oikarinen, DDS, PhD, who took me under his wings after I had presented my ideas for doctoral research. With his straightforward, sincere manner he has guided through the pitfalls and mysteries of scientific research. Professor Aune Raustia, DDS, PhD, was also one of the first persons to push me forward in this study.

I wish to thank the official referees, Docent Pekka Ylipaavalniemi, D.D.S, Ph.D, and Docent Knut Tornes, D.D.S, Ph.D, for their careful revision and constructive criticism of the manuscript. I am deeply grateful to my colleague and co-author, Kaj Finne, DDS, Head of the Department of Oral and Maxillofacial Surgery, Vaasa Central Hospital. From him I have learned the techniques and philosophy of orthognathic surgery, and his open mind and everlasting enthusiasm for everything new have encouraged me during my whole surgical career.

My co-authors Katri Keski-Nisula, DDS, Leo Keski-Nisula, MD, PhD, Sanna Keski-Nisula, MSc, Matti Somppi, DDS, and Docent Heli Forssell, DDS, PhD, deserve my warmest appreciation for their co-work and many interesting discussions. Ms Eija Takkula, Mrs Ann-Charlotte Nickull and Mrs Lilly Hästö have never hesitated to help me in secreterial work. Mrs Sirkka-Liisa Leinonen has kindly and efficiently helped me to express my thought in correct English language.

I warmly thank my father and my late mother, who have always encouraged and supported me in my efforts and decisions. Finally, I express my deepest gratitude to my beloved wife Sari and to our children Katariina, Sakari and Johanna for their support and patience during this long process and for reminding me that there is life outside work and scientific research.

This work was financially supported by the Finnish Dental Society, Vaasa Central Hospital and Oulu University.



## **Abbreviations**

BSSO	bilateral sagittal split osteotomy
TMJ	temporomandibular joint
TMD	temporomandibular disorder
2-PD	2-point discrimination (sensitivity test)
MR	magnetic resonance
IMF	intermaxillary fixation
EMG	electromyography
IAN	inferior alveolar nerve
LN	lingual nerve
PIC	Patient Insurance Center



## **List of original papers**

The thesis is based on the following original articles, which are referred to in the text by numerals I to V:

- I Forssell H, Finne K, Forssell K, Panula K, Blinnikka L-M (1998) Expectations and perceptions regarding treatment: A prospective study of patients undergoing orthognathic surgery. *Int J Adult Orthognath Orthod Surg* 13: 107–113.
- II Panula K, Somppi M, Finne K, Oikarinen K (2000) Effects of orthognathic surgery on temporomandibular joint dysfunction . A controlled prospective 4-year follow-up study. *Int J Oral Maxillofac Surg* 29: 183–187.
- III Panula K, Finne K, Oikarinen K (2001) Incidence of complications and problems related to orthognathic surgery: a review of 655 patients. *J Oral Maxillofac Surg* 59: 1128–1136.
- IV Panula K, Finne K, Oikarinen K (xxxx) Neurosensory deficits after bilateral sagittal split ramus osteotomy of the mandible – the influence of medial side soft tissue handling of the ascending ramus. *Int J Oral Maxillofac Surg* (submitted).
- V Panula K, Keski-Nisula L, Keski-Nisula K, Keski-Nisula S, Oikarinen K (2002) Costs of surgical-orthodontic treatment in community hospital care: An analysis of the different phases of treatment. *Int J Adult Orthognath Orthod Surg* 17: 297–306.

Reprints were made with the permission of the journals.



# Contents

Abstract	
Acknowledgements	
Abbreviations	
List of original papers	
1 Introduction	13
2 Review of the literature	15
2.1 Prevalence of dentofacial deformities	15
2.2 Historical development of orthognathic surgery	16
2.2.1 Mandibular osteotomies	16
2.2.2 Maxillary osteotomies	17
2.2.3 The role of orthodontics in orthognathic surgery	18
2.3 Psychological considerations in orthognathic surgery	18
2.3.1 Psychosocial profiles of patients and their expectations regarding orthognathic surgery	18
2.3.2 Psychological risks and adverse outcomes	20
2.4 Effects of occlusal factors on temporomandibular disorders and masticatory function	22
2.4.1 Temporomandibular disorders (TMD): general view	22
2.4.2 TMD and malocclusion	23
2.4.3 TMD and orthognathic surgery	25
2.4.4 Masticatory performance and malocclusion	28
2.5 Complications and adverse effects of orthognathic surgery	29
2.5.1 Nerve injuries	29
2.5.2 Complications in TMJ	30
2.5.3 Vascular complications	31
2.5.4 Relapse	32
2.5.5 Infection	32
2.5.6 Other complications	33
2.6 Costs of orthognathic surgery	34
3 Aims of the study	35

4	Material and Methods	36
4.1	Patients	36
4.2	Methods	38
4.2.1	Psychological considerations in orthognathic surgery	38
4.2.2	Effects of orthognathic surgery on TMD and masticatory function	39
4.2.3	Complications and adverse effects of orthognathic surgery	39
4.2.4	Costs	41
4.3	Statistics	41
5	Results	43
5.1	Psychosocial profiles of patients	43
5.2	Effects of orthognathic surgery on TMD and masticatory function	45
5.3	Complications and problems	46
5.4	Costs	50
6	Discussion	53
6.1	Methodological aspects	53
6.2	Expectations and perceptions regarding orthognathic surgery	54
6.3	Effects of orthognathic surgery on TMD and masticatory function	57
6.4	Complications	60
6.5	Costs	62
6.6	General comments and clinical implications	62
7	Conclusions	65
	References	
	Original papers	

# 1 Introduction

Orthognathic surgery is a process in which dentofacial deformities and malocclusions are corrected with orthodontics and surgical operations of the facial skeleton, sometimes combined with various soft tissue procedures. The term *orthognathic* originates from the Greek words *orthos*, 'straight', and *gnathos* 'jaw'. It is possible to correct, or "straighten", deformities separately in either the maxilla or the mandible with many types of surgical techniques or to do procedures concurrently on both jaws (bimaxillary operations). The treatment does not change only the bony relations of the facial structures, but soft tissues as well, and by doing so, may alter the patient's appearance. Contemporary orthognathic techniques can be applied in many fields of surgery: apart from correcting congenital and posttraumatic malocclusions, they can be used in the treatment of the obstructive sleep apnea syndrome (Riley *et al.* 1993), to improve phonetics (Vallino 1990) or even in tumour resections (Grime *et al.* 1991, Sailer *et al.* 1999).

In childhood and adolescence, some skeletal malocclusions can be treated merely orthodontically and with various functional therapies utilizing natural growth, but once growth has ceased, this is no longer possible and additional surgery is needed. Some skeletal malocclusions can, to a certain extent, be treated with only orthodontics even in adulthood. This type of treatment is called camouflage, because it most often fails to correct the whole discrepancy underlying the malocclusion, and a certain degree of compromise must be accepted. Treatment of this kind cannot usually produce equally stable results as treatment combined with surgery, and life-time orthodontic retention is therefore often needed. Orthognathic surgery gives an opportunity to obtain better occlusal, skeletal and cosmetic results. Many psychosocial studies have shown that cosmetic motives for seeking treatment seem to be quite common, but there may be socio-cultural differences in this respect.

The modern history of orthognathic surgery is rather short. It was actually only in the 1970's that orthognathic surgery gradually became a routine choice of treatment. Various benefits of orthognathic surgery have been reported, including better masticatory function (Karabouta & Martis 1985, White & Dolwick 1992, Zarrinkelk *et al.* 1996), reduced facial pain (Magnusson T *et al.* 1986, 1990, Rodrigues-Garcia *et al.* 1998), more stable results in severe discrepancies (Proffit *et al.* 1992) and improved facial esthetics (Tucker 1995),

but due to the relatively short history of orthognathic surgery, much of the literature is scattered and mostly deals with various technical improvements, short-term outcomes, descriptions of complications and the stability of the treatment results. It has been postulated that orthognathic surgery may also carry a risk of temporomandibular disorders (TMD) or may have no benefit for TMD (Sostman *et al.* 1991, Smith *et al.* 1992, Onizava *et al.* 1995).

Analyses of the risks and benefits of orthognathic surgery are few, as are also longitudinal, controlled long-term follow-up studies concerning TMD and masticatory function. Although orthognathic surgery is a long, resource-demanding process, cost analyses are very few.

Because the health-related and functional benefits of the correction of skeletal malocclusion seem to be controversial and the economic consequences remain largely unknown, the purpose of this study was to obtain an overall impression of the indications and benefits of contemporary orthognathic surgery with special reference to the related risks, adverse outcomes and costs. The study focused on the common treatment of congenital skeletal malocclusions; the specific features of orthognathic surgery in conjunction with obstructive sleep apnea treatment, posttrauma or tumour surgery were excluded. The influence of orthognathic surgery on phonetics was also beyond the scope of this study.

## 2 Review of the literature

### 2.1 Prevalence of dentofacial deformities

There are no exact epidemiologic data of dentofacial deformities in adult populations, but Proffit and White (1991) estimated, on the basis of United States Public Health Service studies from the 1960's, that the prevalence of skeletal Class II malocclusions in the USA population was roughly 10%, about 3% of which were severe enough and at the right age to warrant surgery, mostly (70%) mandibular surgery. The corresponding figures for skeletal Class III malocclusions were 0.6% and 21%, and for severe open bite 0.6% and 16%. Recently, Proffit *et al.* (1998) gathered malocclusion data from the National Health and Nutrition Examination Survey (NHANES III) in the USA and found approximately 20% of the US population to have deviations from the ideal bite, and 2% of these were severe enough to be disfiguring and at the limit for orthodontic correction capacity. In this study, the prevalence of severe Class II malocclusions (defined as > 6 mm overjet) was found to be 4.3% in the age groups of 18–50 years, while that of Class III malocclusions (defined as  $\geq -3$  mm overjet) was 0.3%. In Scandinavia such information is mainly available for children: malocclusion frequencies of approximately 40% to 75%, or even higher, have been reported (Heikinheimo 1989, Permert *et al.* 1998), and 10% of young people would be in definite need for (orthodontic) treatment. In the Netherlands, a nationwide survey showed that Angle Class II dental relation was present in 28% and maxillary overjet of more than 5 mm in 23% of the population. An objective need for orthodontic treatment was recognized in 39% of the population (Burgersdijk L *et al.* 1991). If the data from the USA (Proffit & White 1991) are adjusted to Finland, although recalling that populations differ from each other in many aspects, there would be 510 000 people with skeletal Class II, approximately 15 000 of whom would need surgery, and 30 600 and 6400 subjects with Class III, correspondingly. According to the more recent approximation of Proffit *et al.* (1998), a million Finns (20%) would have deviations from ideal bite, and 20 000 (2%) of them would be in need of surgery. Since approximately 400 orthognathic operations are performed in Finland annually, it would take 50 years to operate these patients, assuming that no new malocclusions would appear in the meantime. Therefore, these scores seem quite high as far as the treatment resources and

costs are concerned and are based solely on morphologic deviations. There also exists a controversy as to the definition of malocclusion and the indicators for treatment (Heikinheimo 1989). However, other relevant factors apart from purely anatomical ones, such as psychosocial and biophysiological, also affect the need and demand for treatment.

## **2.2 Historical development of orthognathic surgery**

### ***2.2.1 Mandibular osteotomies***

The historical development of orthognathic surgery has not been uniform and continuous but has rather followed a stepwise, intermittent course. The early-phase surgery was mainly limited to the mandible, while maxillary procedures were to come later. Orthognathic surgery was originally developed in the United States of America (Steinhäuser 1996). The first mandibular osteotomy is considered to be Hullihen's procedure in 1849 to correct a protrusive malposition of a mandibular alveolar segment caused by a burn (Hullihen 1849). Osteotomy of the mandibular body for the correction of prognathism was first carried out in 1897 as so called 'St Louis operation'. The osteotomy was performed by Vilray Blair, who later described several methods to correct maxillofacial deformities and was the first to present a classification of jaw deformities: mandibular prognathism, mandibular retrognathism, alveolar mandibular and maxillary protrusion and open bite. He was also the first to underline the importance of orthodontics in treatment. (Steinhäuser 1996). The first phase of development in the USA came to an end at World War I (WW I), when surgeons had to concentrate on trauma surgery.

Not much progress was made in Europe during the first phase of orthognathic history. Berger (1897) described a condylar osteotomy for the correction of prognathism. This technique was elaborated by others, but the results were not satisfactory due to problems of relapse and open bite. Only slight development took place between the two World Wars (second phase), and during WW II, surgeons were again committed to the treatment of facial injuries. The concentration on trauma surgery was not, however, only a disadvantage to the development of orthognathic surgery, but also helped in many ways to apply these experiences to the principles of orthognathic surgery.

The third phase, which began in the early 1950's, was a period of rapid development in the whole field of orthognathic surgery. In 1954, Caldwell and Letterman developed a vertical ramus osteotomy technique, which had the advantage of minimizing trauma to the inferior alveolar neurovascular bundle. This method could be used instead of body osteotomy to correct mandibular excess.

Europe now became the center of progress. Pupils of the 'Vienna School' of maxillofacial surgery, Trauner and Obwegeser (1957), introduced intraoral bilateral sagittal split ramus osteotomy (BSSO), although the first description was published as early as 1942 (Schuchardt). The technique was further modified by Dal Pont (1961), Hunsuck (1968) and Epker (1977) among others. It was a versatile procedure that

allowed corrections in all three planes of space without a need for a bone graft. There were, however, still many problems and much hesitation before this procedure made a breakthrough in the late 1970's and now sagittal split osteotomy has become the most commonly performed mandibular procedure (Wyatt 1997). The risk of damage to the inferior alveolar nerve still remains. The introduction of an internal rigid fixation method — bone screws and plates — instead of 5- to 6- week intermaxillary fixation radically improved patient convenience (Steinhäuser 1996). This new method was motivated by innovations within trauma surgery, from where it was gradually applied to orthognathic surgery. Biodegradable osteosynthesis material (Suuronen R *et al.* 1999) and application of the principles of distraction osteogenesis represent the latest innovations in orthognathic surgery.

There seems to exist only one report on early Finnish orthognathic surgery, closed condylotomy for the correction of prognathism in 31 patients (Tasanen *et al.* 1981), although osteotomies for correction of dentofacial deformities have been performed ever from the 1960's.

### 2.2.2 Maxillary osteotomies

Although Cheever was the first to do downfracture of the maxilla as early as 1864 to resect a nasopharyngeal mass in two patients, it took decades until further maxillary procedures were attempted (Moloney & Worthington 1981). Between the World Wars in 1921, 72 years after Hüllihen's first mandibular osteotomy, Wassmund reported his initial attempt to perform maxillary osteotomy. Wassmund did not mobilize the maxilla, but employed orthopedic traction postoperatively to position the maxilla. (Turvey & White 1991). Again, it was not until the third phase of the development of orthognathic surgery in 1960 that Obwegeser started to perform maxillary surgery and described a large series of LeFort I osteotomies in 1969. That marked the beginning of a new era in the correction of maxillofacial deformities: before the mid-1960's, dentofacial deformities were treated by performing mandibular surgery, although the patient would also have benefited from complementary or exclusive maxillary surgery. This technique was just as revolutionary in the maxilla as sagittal split osteotomy had been in the mandible: the maxilla could now be moved in all three planes of space. The major concerns had been intraoperative bleeding, revascularization and healing of the maxilla. After studies of vascular perfusion and the anatomy and relevance of the maxillary artery, it was found that the most important thing would be to preserve a wide, intact palatal and maxillary soft tissue pedicle attached to the osteotomized segments. This allows good healing and minimizes the risk of tissue necrosis. (Bell *et al.* 1975, Turvey & Fonseca 1980).

The improvement of surgical techniques, and the progress in anesthesia, enabled surgery on two jaws, called bimaxillary surgery, and the introduction of rigid internal fixation made it more predictable and decreased morbidity. Köle had, as early as 1959, performed simultaneous segmental osteotomies on both jaws (Köle 1959), but the first total two-jaw operation was done by Obwegeser in 1970. This technique facilitates the correction of extensive dentofacial deformities in a single operation.

### ***2.2.3 The role of orthodontics in orthognathic surgery***

Orthodontics is an essential part of modern orthognathic surgery. This was stressed by the surgeon Converse and the orthodontist Horowitz in 1969. It is important that the dental arches are properly aligned before the operation. This makes accurate correction of the skeletal discrepancy possible, not only in the antero-posterior and transverse direction, but also vertically.

Before 1960's the surgical correction of dentofacial deformities was done either without patient ever having orthodontic treatment, after orthodontic appliances had been removed, or, occasionally before any orthodontics was begun. Coordinating the two types of treatment more carefully was not highly appreciated.

At that time, rigid arch bar constructions, familiar from trauma surgery, were used perioperatively when needed. Technical development of orthodontic brackets and steel rectangular wires, edgewise technique, could give excellent and sufficiently rigid control of occlusion to be utilized also in surgery. The more precise tooth movements allowed finishing of the occlusion postoperatively.

The introduction of occlusal wafer splint was an important step in allowing surgery to occur before orthodontic detailing of the occlusion was completed. Consequently, the total treatment time reduced significantly, when some type of tooth movements could be more efficiently accomplished postoperatively. (Proffit & White 1991).

## **2.3 Psychological considerations in orthognathic surgery**

### ***2.3.1 Psychosocial profiles of patients and their expectations regarding orthognathic surgery***

Orthognathic surgery is a complex process leading to changes in the appearance and functions of the dentofacial structures, including respiration, swallowing, speech and mastication. These alterations take place in a single moment during the operation in contrast to the traditional orthodontics in children, which produces small, gradual changes during growth. Thus, orthognathic surgery may seriously challenge the patient's capacity to adapt. This adaptation may be easier if the psychosocial indications and implications are thoroughly evaluated prior to any treatment and also during the presurgical phase.

Appearance is a major concern for many people seeking orthognathic surgery. Current society seems to highly value cosmetic characteristics in many branches of life. The face is the area of one's body that maximally determines physical attractiveness. It is a primary means of identification and a rich source of nonverbal communication (Cunningham *et al.* 1995). Severe craniofacial deformities, such as cleft lip and palate, Down's syndrome, Crouzon and Pierre-Robin syndromes and hemifacial microsomia, may cause significant psychosocial problems (Pertchuk & Whitaker 1982, 1985, 1987).

Craniofacial reconstruction of such defects has resulted in improved psychosocial well-being, including improved self-esteem and self-assessment of facial appearance (Arndt *et al.* 1986). Orthognathic surgery differs from the correction of congenital craniofacial anomalies in that the changes in appearance are less dramatic, but even in these less extreme conditions, effects on personality may be recognizable (Kiyak & Bell 1991).

The motivations of orthognathic surgery candidates to seek treatment have been studied quite extensively during the short history of surgical orthodontic treatment, but many of the early reports were retrospective, case reports and not longitudinal, and they were seldom based on structured questionnaires (Kiyak & Bell 1991). Motives include esthetic improvement, better functioning of the masticatory organs, pain relief and recommendations from others, such as a dentist or family members. Desire for esthetic improvement, however, has been expressed as the major reason for seeking orthognathic surgery in several studies (Wictorin *et al.* 1969, Laufer *et al.* 1976, Pepersack & Chausse 1978, Kiyak *et al.* 1981, Heldt *et al.* 1982, Jacobson 1984, Flanary *et al.* 1985, Kiyak & Bell 1991, Finlay *et al.* 1995) or has obviously been a more important motive than functional (De Boever *et al.* 1996, Rodrigues-Garcia *et al.* 1998). Functional improvement is also considered an important factor by a number of authors (Wictorin *et al.* 1969, Laufer *et al.* 1976, Pepersack & Chausse 1978, Jacobson 1984, Flanary *et al.* 1985, Athanasiou *et al.* 1989a, Finlay *et al.* 1995). Patients may also believe that they are more easily accepted for orthognathic treatment if they have a functional problem rather than an esthetic one (Wictorin *et al.* 1969). Most often, however, the patients have both functional and esthetic concerns (Kiyak & Bell 1991), and only the proportional importance of these factors varies.

Edgerton and Knorr (1971) described two types of motivation, external and internal. External motivations include the need to please others, “paranoid” ideas and beliefs that one’s career or social ambitions are being thwarted by physical appearance. These motivations require a change in the patient’s personal environment rather than surgery to solve the problem (Cunningham *et al.* 1995).

Internal motivation is usually a more valid form of motivation and includes long-standing inner feelings about deficiencies in one’s appearance. These persons are better candidates for surgery. Many patients naturally exhibit a combination of both characteristics.

Studies report diverse results on the gender differences in personality characteristics before orthognathic surgery. Kiyak and Bell (1991) found that although women scored higher on scales of neuroticism (emotional lability and overreactiveness), both men and women scored within the normal range, notably better than the cosmetic surgery population. Sex differences were not significant in either postsurgical satisfaction or self-reports of pain. Males and females in the orthognathic group did not differ on extroversion, self-esteem or overall body image scores in the presurgical assessment.

The associations of the type of malocclusion with the psychological features of the person have been studied in some investigations. Helm *et al.* (1985) found that unfavourable self-perceptions of facial appearance were expressed most often by young adults with extreme overjet, deep bite and crowding. In a study by Gerzanik *et al.* (2002), the psychologic profiles of 100 Class II and Class III patients were significantly different preoperatively and showed different dynamics postoperatively. Patients with Class III deformity felt less attractive than Class II patients preoperatively, and their grading of

attractiveness/self-confidence improved significantly more postoperatively than that of Class II patients. The vast majority of Class III patients undergoing orthognathic surgery suffered from psychologic and functional problems related to their appearance prior to treatment, and esthetic improvement was the driving force behind their decision to seek treatment (Zhou *et al.* 2001).

In summary, the patients referred for surgery are nearly always within the psychologically normal range in view of self-esteem, body image, neuroticism and mood states (Kiyak & Bell 1991). Most of the patients' expectations are satisfactorily met at all ages (Ostler & Kiyak 1991, Pogrel & Scott 1994). These findings are different from those of the cosmetic surgery population. Recently, Meningaud *et al.* (2001) evaluated prospectively in a multicentre study patients scheduled for cosmetic surgery (blepharoplasty, face lifting, cervical liposuction, baldness surgery, otoplasty and chin surgery) and found that these patients had different psychological profiles compared to the controls. Their social anxiety and depression rating indexes were higher, and the examiners concluded that the cosmetic surgery population presented a significant state of psychological vulnerability.

There are only two reports from Finland dealing with the motivations to seek orthognathic surgery or the satisfaction with the results (Le Bell *et al.* 1993, Nurminen *et al.* 1999), and the patient series in both cases were rather small. The first study reported esthetics to be the main reason for seeking treatment for 78% of the patients. The second study found the most common reasons for seeking professional help to be problems in biting and chewing (68 %), the second most important motive being dissatisfaction with facial appearance (36%). TMJ problems were present in 32% and head symptoms, mainly headache, in 32%. Nearly 100% of the patients were satisfied with the outcome of the treatment. In studies from Sweden, esthetic motives for seeking treatment were approximately as important as functional ones (Wictorin *et al.* 1969, Garvill *et al.* 1992, Ek *et al.* 1997), but in a Danish study, functional reasons were cited more often than esthetic reasons (Athanasίου *et al.* 1989a).

### ***2.3.2 Psychological risks and adverse outcomes***

Patients having orthognathic surgery seem to have fewer postoperative problems than patients having cosmetic surgery, such as rhinoplasty or mammoplasty (Heldt *et al.* 1982). Cunningham *et al.* (1995) present some possible reasons for this difference: (1) orthognathic surgery patients receive more support from their friends and family than do cosmetic surgery patients because the operation is considered necessary for both esthetic and functional reasons, and treatment for functional reasons is socially better accepted. This attitude may be changing now that cosmetic surgery seems to be becoming socially more acceptable; (2) orthognathic surgery patients are often referred for treatment instead of initiating the visit themselves; (3) orthognathic surgery patients have never had an image of "normality"; (4) orthognathic surgery patients are often young and may thus have a better adaptation capacity.

The rate of dissatisfaction with rhinoplasty seems to vary from 5% to 40%, whereas dissatisfaction with orthognathic surgery is seen in less than 5% of cases, and as mentioned in the preceding chapter, most of the expectations of orthognathic surgery patients are fulfilled. There may, however, be some postoperative problems. A patient's dissatisfaction with surgery will not always manifest itself in a straightforward manner, but can be expressed as a request for further surgery or litigation (Cunningham *et al.* 1995).

Macgregor (1981) has presented three major categories for the reasons for dissatisfaction:

1. patient-dependent factors: multiple or serious psychological problems, unrealistic expectations, external reasons for surgery,
2. surgeon-dependent factors: lack of empathy for postoperative problems, too much hurry with evaluations or too little preoperative preparation,
3. surgeon-patient interaction: poor communication or personality conflict.

In the short term, postsurgical discomfort and functional problems may cause dissatisfaction.

Neuroticism may also have a negative effect on the early postsurgical phase but not on the long-term outcome (Kiyak & Bell 1991). Prolonged postoperative orthodontic treatment may be a reason for dissatisfaction (Kiyak & Bell 1991, Pogrel & Scott 1994), as may also postoperative neurosensory disturbances (Kiyak & Bell 1991, Finlay *et al.* 1995).

Depression is a relatively common finding following any surgical procedure, and it has also been reported after orthognathic surgery. It is most evident immediately after surgery and usually gradually declines after that. During this time, additional support is needed from the family and the medical personnel. (Cunningham *et al.* 1995). Infection, use of sedatives, low-calorie diet associated with an increased corticotropin release factor concentration and insufficient preoperative information about the immediate consequences of the operation have been presented as predisposing factors (Stewart & Sexton 1987).

Dysmorphophobia means that a person believes him/herself to be unattractive although his or her appearance is within normal limits. Patients may become completely preoccupied with this thought. Although they might benefit from surgery, the appropriate initial treatment should be psychiatric rather than surgical. (Cunningham *et al.* 1995).

Pogrel and Scott (1994) conclude that most orthognathic surgery patients are psychologically normal, routine preoperative psychological evaluation is not indicated, and even a psychiatric diagnosis does not preclude surgery. A cornerstone for successful outcome is a thorough evaluation of the patient's expectations and careful preoperative information of the surgical process. Functional improvement from the treatment should be emphasized in consultations rather than the need to make esthetic improvements as the only reason for treatment. A good functional outcome may help the patient to accept possible adverse consequences. If the patient mostly focuses on esthetics, the chances of dissatisfaction are greater. (Kiyak & Bell 1991).

Spouses and significant others could be interviewed to ascertain their attitude (Pogrel & Scott 1994). The current use of rigid internal fixation decreases the distress caused by intermaxillary fixation (Stewart & Sexton 1987). A delay in starting treatment may be a

benefit, because it will show how keen the patient really is to have surgery. Time-consuming preoperative orthodontics partly serves this purpose.

## **2.4 Effects of occlusal factors on temporomandibular disorders and masticatory function**

### ***2.4.1 Temporomandibular disorders (TMD): general view***

Temporomandibular disorders (TMD) refer to a variety of medical and dental conditions affecting the temporomandibular joint (TMJ) and/or the masticatory muscles as well as contiguous tissue components. Although specific etiologies, such as degenerative arthritis and trauma, underlie some TMD, these conditions as a group have no common etiology or biologic explanation and comprise a heterogeneous group of health problems whose signs and symptoms overlap but are not necessarily identical. The term 'TMD' has commonly been used to characterize a wide range of conditions diversely presented as pain in the face or the jaw joint area, headaches, earaches, dizziness, masticatory muscle hypertrophy, limited mouth opening, closed or open lock of the TMJ, abnormal occlusal wear, clicking or popping sounds in the jaw joints and other complaints. (National Institutes of Health Technology Assessment 1997). The prevalence of at least one sign of TMD in non-patient adult populations has varied between 40% and 85% (Kuttila 1998), but the prevalence of severe dysfunction, according to Helkimo's clinical dysfunction index (1974), is lower than 1% (Salonen 1990). Rauhala *et al.* (2000) found, in an epidemiologic study of the Northern Finland 1966 Birth Cohort, that 12% of men and 18% of women had suffered from facial pain during the past year, while clicking of the TMJ was present in 21% of men and 28% of women, and the prevalence of more severe symptoms was 13% or less. Distal occlusion was one of the factors related to TMD. Fluctuation of signs and symptoms of TMD is usual, but awareness of these problems seems to increase with age (Kuttila 1998). Magnusson *et al.* (2000) examined, in a longitudinal study, the status of the masticatory organ during a 20-year period and noticed substantial fluctuation of both reported and clinical signs and symptoms of TMD, but progression to severe pain or dysfunction was rare.

Sipilä *et al.* (2002) also subjected a subpopulation of the Northern Finland 1966 Birth Cohort to double-blinded case-control, anamnestic and clinical examinations. Facial pain associated significantly with TMD, and most of the cases belonged to the myogenous subgroup of TMD. Anamnesticly, stress was the most often reported provoking factor for facial pain.

The reasons for headache may be numerous, and some of them have been associated with occlusal factors and masticatory dysfunction. Significant associations have been reported with clenching or grinding of teeth, malocclusion, tenderness to palpation of the masticatory muscles or impaired mobility and the frequency and intensity of headache (Lous & Olesen 1982, Wanman 1987, Sonnesen *et al.* 1998). Abnormal tonic

hyperactivity in the masticatory muscles and the neck may be an important source of pain in these patients.

Placebo-controlled studies with occlusal adjustment with or without splint therapy in patients with muscle contraction headache (MCH), common migraine (CM) and combination headache (MCH+CM) have shown a decrease in headache frequency and a correlation with the decrease of the mandibular dysfunction index (Forsell *et al.* 1985, 1986, 1987). Patients with MCH and CM benefited most from the therapies.

At present, TMD is generally considered to have a multifactorial etiology. The current diagnostic classifications of TMD are based on signs and symptoms rather than etiology, in line with conditions of the lumbo-sacral spine, such as low back pain (National Institutes of Health Technology Assessment 1997). Greene (2001) has provocatively suggested that not only are the old mechanistic etiologic concepts incorrect, but two of the most popular current concepts (biopsychosocial and multifactorial) are also seriously flawed. Nevertheless, he continues to add that even in the absence of full understanding of etiology, good conservative care can be provided, but aggressive and irreversible treatments should be avoided.

As for etiology and diagnosis, a number of treatment modalities have been presented: supportive patient education; pain control with medication; physical therapy; various intraoral appliances; occlusal therapy; and surgical approach (National Institutes of Health Technology Assessment 1997). Forsell *et al.* (1999) found in their systematic review of the literature several weaknesses in many of the studies dealing with occlusal adjustments and splint therapies: small sample sizes (lack of power); short follow-up periods; lack of blinding of examiners; numerous and varying outcome measures. The results suggested that controlled clinical trials give some evidence of the use of splints, but sufficient evidence for occlusal treatment is lacking. Vallon & Nilner (1997) studied in a controlled 2-year follow-up survey the effects of occlusal adjustments on TMD and concluded that only single patients improved from counseling alone, a few more improved if one other kind of treatment, e.g. occlusal adjustment, was added to counseling, but the majority required a comprehensive treatment program.

### ***2.4.2 TMD and malocclusion***

The cause-and-effect relationship between malocclusions and TMD is controversial. One of the first practitioners to assume a relationship between TMJ and occlusion was Costen (1934), an otolaryngologist who noticed that many of his patients with pain in the TMJ region benefited from alteration of their occlusion, especially in the vertical dimension.

Associations between certain features of occlusion and TMD have been mentioned in many reports. Relationships have been found between open bite and TMD in some studies (Riolo *et al.* 1987, Henrikson *et al.* 1997, Sonnesen *et al.* 1998) and between deep bite and TMD (Kerstens *et al.* 1989). A significant association of TMD with unilateral crossbite and midline displacement has also been reported (Sonnesen *et al.* 1998). Abnormal overbite and overjet may be associated with more extensive deviation in the temporal and condylar form, particularly when combined with age, which has been

interpreted as evidence to support the idea that longer exposure to malocclusion may be associated with more extensive TMJ changes (Solberg *et al.* 1986). O’Ryan & Epker (1984) have also presented that dentofacial deformities and malocclusions may lead to adaptive changes within the TMJ. Schellas (1989) hypothesized, interestingly, based on his MR image study that TMJ pathology may be the cause of malocclusion rather than vice versa. He concluded that it is critically important to diagnose significant TMJ pathology before attempting permanent occlusal adjustment, including orthognathic surgery.

Several studies have reported more TMD in skeletal Class II (or excessive overjet) than in other dentofacial deformities, e.g. skeletal Class III (Upton *et al.* 1984, Riolo *et al.* 1987, Magnusson *et al.* 1990, White & Dolwick 1992, Le Bell *et al.* 1993, Fernandez Sanroman *et al.* 1997, Sonnesen *et al.* 1998). A tendency towards more TMD in patients with normal or low mandibular plane angles compared to patients with high mandibular plane angles has been observed (Kerstens *et al.* 1989, White & Dolwick 1992).

There are also a number of studies reporting no significant association between occlusal relationships and TMD. There are studies that have failed to confirm significant relationships between TMJ or muscle tenderness and Angle’s classification or any occlusal contact relationships, or between functional occlusal relationships and TMD (Sadowski & Beyole 1980, Bush 1985, Egermark-Eriksson *et al.* 1987). In their review articles, Reynders (1990) and Seligman & Pullinger (1991) concluded that there existed no scientific evidence for a causal relationship between occlusion and TMD. Wadhwa *et al.* (1993) studied three patient groups, one with normal occlusions, one with untreated malocclusions and one with orthodontically treated malocclusions. They concluded that the role of orthodontic treatment in either the precipitation or the prevention of TMD remains questionable. Although considerably high rates of prevalence of uni- or bilateral disc displacements, clicking of the joints and pain in the TMJ or masticatory muscles have been found in pre-orthognathic surgery patients examined clinically and with arthrography, no association could be seen between signs or symptoms and the type of dentofacial deformities (Roberts *et al.* 1987, Dahlberg *et al.* 1995). Although Kirveskari and Alanen (1993) believe that there is insufficient evidence to warrant the rejection of the hypothesis that occlusal factors are part of the causal complex of TMD, it seems that, with the present weak and varied epidemiologic data, there is little predictive value in the attempts to relate a specific dentofacial malocclusion to an individual’s risk for developing TMD.

The available evidence seems insufficient to warrant prophylactic modalities of therapy. The statement of National Institutes of Health Technology Assessment (1997) suggests that surgical interventions (TMJ) should be considered in the small percentage of patients with persistent and significant pain and dysfunction who show evidence of pathology or suggest that an internal derangement of the TMJ is the source of their pain and dysfunction, and for whom more conservative treatment has failed.

### 2.4.3 TMD and orthognathic surgery

The prevalence of various signs and symptoms of TMD prior to orthognathic surgery has varied between studies from 14% up to 97% of subjects (Laskin *et al.* 1986, Kerstens *et al.* 1989, DeClercq *et al.* 1995, Karabouta & Martis 1985, Scheerlinck *et al.* 1994, White & Dolwick 1992, Fernandez Sanroman *et al.* 1997, Schneider & Witt 1991, Link & Nickerson 1992). This great variation may be due to differences in referral patterns or motivations to seek treatment (Laskin *et al.* 1986) or selection of study subjects as in the study of Link & Nickerson (1992).

An important goal of orthognathic surgery is to improve the masticatory function and to minimize TMD. Most of the earlier studies seem to suggest that this goal can be achieved, but some controversy also exists. Most of the studies that have reported positive effects on TMD after orthognathic surgery report this association with skeletal Class II deformity (or mandibular retrognathia/hypoplasia or Angle Class II). Decrease of signs and symptoms by more than 50% compared to the preoperative state was reported to occur by Karabouta and Martis (1985), Kerstens *et al.* (1989), Magnusson *et al.* (1990), De Clercq *et al.* (1995) and White and Dolwick (1992), while subjects with skeletal Class III (or mandibular prognathia/hyperplasia) or patients with a high mandibular plane angle ( $> 32^\circ$ ) seem to benefit considerably less (Kerstens *et al.* 1989, White & Dolwick 1992, De Clercq *et al.* 1995). However, improvement of TMD even in Class III patients may be attained with orthognathic surgery, as shown by the studies of Ingervall *et al.* (1979), Magnusson *et al.* (1986, 1990), Le Bell *et al.* (1993).

Disc positions and internal derangements in orthognathic surgery patients have been assessed with TMJ imaging techniques (arthrography, MR) in some studies, and slight improvements in disc position, pain and joint sounds after treatments have been seen (Eriksson *et al.* 1990, Gaggl *et al.* 1999).

Egermark *et al.* (2000) studied 52 patients with malocclusions, who had undergone orthognathic surgery involving LeFort I and/or sagittal split osteotomy. Approximately 5 years after surgery, the patients were examined for TMD. Some of them had reported recurrent or daily headaches before treatment, but at the 5-year examination, only two patients reported having a headache once or twice a week, while the others suffered from headaches less often or had no headache at all. The authors concluded that orthognathic surgery results in improvement of TMD, including headaches. A few other studies have also found improvement in headache after orthognathic surgery, but they have similar shortcomings, as will be mentioned at the end of this chapter (Magnusson *et al.* 1986, 1990, LeBell *et al.* 1993, Nurminen *et al.* 1999, Westermarck *et al.* 2001). It seems, however, that occlusal adjustment may have a favourable influence on headache, especially on muscular contraction type headache.

Orthognathic surgery may not have only beneficial effects on TMJ function, but also adverse consequences. The prevalence of TMD after orthognathic surgery among preoperatively asymptomatic patients has varied from 3.7% to 11.9% (Karabouta & Martis 1985, White & Dolwick 1992, Scheerlinck *et al.* 1994, Kerstens *et al.* 1989, De Clercq *et al.* 1995). As fluctuation of TMD is common (Kuttila 1998, Magnusson *et al.* 2000), this may also be part of normal variation. Thus, an investigation with a non-treatment control group would be indicated, as planned in the present study.

Table 1. shows some demographic data of the reports on the influences of orthognathic surgery on TMD.

There are also studies that report only minimal or no specific change in TMD after orthognathic surgery. Sostmann *et al.* (1991) evaluated 86 orthognathic surgery patients with Helkimo's anamnestic and dysfunction indexes and found no relationship between TMD and the type of malocclusion, the surgical approach and molar support before and after surgery, but concluded that the possible beneficial effect was achieved in certain symptoms, such as TMJ pain and sounds. A modification of Helkimo's index was also used in a prospective study of 22 patients operated with BSSO (Smith *et al.* 1992). Subjectively, muscular pain, headache, joint noise and parafunctional habits decreased, but clinical dysfunction remained unchanged and partly even deteriorated. The prospective multicenter study of Rodrigues-Garcia *et al.* (1998) explored the relationship between severe Class II malocclusion and TMD before and 2 years after BSSO. The patients were evaluated with the Craniomandibular Index (CMI), the Peer Assessment Rating (PAR) Index and symptom questionnaires. The results showed significant improvement in occlusion, CMI and muscle pain, reduction in subjective pain and discomfort and decrease in clicking upon opening. On the other hand, crepitus in the TMJ increased and the magnitude in the change of muscular pain was not related to the severity of the pretreatment malocclusion, and the authors concluded that the results do not support the theory that TMD is related to Class II malocclusion. However, the subjects of this study were mostly not seeking treatment for TMD: only 28% of patients reported TMD as the reason for seeking treatment. The Craniomandibular Indexes (CMI) and Dysfunction Indexes (DI) used in the examinations of the patients showed preoperative mean scores of only 0.14 and 0.13 on a scale from 0 to 1.0. Onizava *et al.* (1995) investigated alterations in TMD after orthognathic surgery in a series of 30 patients and 30 healthy volunteers followed up for 6 months. They found no significant difference in TMD between the two groups and concluded that alterations of TMJ symptoms do not always result from the correction of malocclusion.

There appears to be a high range of variation in the prevalence of signs and symptoms of TMD in the orthognathic surgery population prior to treatment, but in several studies, a significant number of patients with dentofacial deformity and TMD have experienced improvement of their symptoms after orthognathic surgery, while, on the other hand, some preoperatively asymptomatic subjects may have developed TMD postoperatively. There are, however, many weaknesses in most of these studies: there are no non-treatment control groups or the patient samples are small, follow-up is short or the studies are retrospective, and IMF has often been used instead of contemporary internal rigid fixation.

*Table 1. Reported signs and symptoms of TMD in orthognathic surgery populations in various studies. There is a lot of variation in the ways how TMD is reported.*

Study	Type of study	No. of subjects	Follow-up	Type of malocclusion	Preop. TMD (%)	Post-op. TMD (%)	Improved TMD (%)	New TMD in pre-operatively asympt. subjects	TMD (%) by diagnosis: preop/postop. %
Westermarck <i>et al.</i> 2001	Retro	1516	2 yrs	Various, defined by mandibular diagnosis	39	21	(headache↓)	–	Prognathia: 41/24 Retrogn: 45/34 Open bite: 42/27 Laterogn: 62/32
Gaggl. <i>et al.</i> 1999	Prosp	25	3 mnth	Angle Class II	76 (disc displac.)	56	(pain, joint noises↓)	–	–
Rodrigues-Garcia <i>et al.</i> 1998	Prosp	124	2 yrs	Class II	26.6 (click) 4 (crep)	10.5 12.9	(muscle pain↓)	–	–
Athanasίου <i>et al.</i> 1996	Prosp	43	6 mnth	Skel. vertic. excess	–	–	–	–	Open bite: 62/77* VME: 88/71*
De Clercq <i>et al.</i> 1995	Retro Selected	143	≥ 6 mnth	Mandibular hypoplasia	26.5	17.8	–	11.9	Normal/low angle: 30/15 High angle: 17/26
Scheerlink <i>et al.</i> 1994	Prosp Selected	103	24–60 mnth	Mandibular hypoplasia	45.6	–	68	10	–
Smith <i>et al.</i> 1992	Prosp	22	?	Mand. hypopl.	–	–	(muscle pain↓)	–	–
White & Dolwick 1992	Retro	75	2 yrs	Various	49.3	–	89.1	7.9	Class II: 61/28 Class III: 14/13
Schneider & Witt 1991	Prosp	25	0.5–1.8 yrs	Mand. progn	80 (crep+click)	64	–	–	–
Magnusson <i>et al.</i> 1990	Prosp	20	1 yr	Mandibular progn/retrogn	–	–	(Ai, Di↓) (headache↓)	–	–
Kerstens <i>et al.</i> 1989	Prosp	480	≥ 1 yr	Various	16.2	–	66	11.5	Norm/low angle improved most
Karabouta & Martis 1985	Prosp	280	9–36 mnth	Mandibular deformities	40.8	11.1	–	3.7	Prognathia: 34/7 Retrogn: 58/1 Open bite: 57/2 Laterogn: 33/2
Magnusson <i>et al.</i> 1985	Prosp	20	1–2.5 yrs	Mostly mand. progn.	–	–	(Ai, Di↓) (headache↓)	–	–
Ingervall <i>et al.</i> 1979	Prosp	18	10 mnth	Mand. progn.	17	0	–	–	–

Abbreviations: crep = crepitus, click = clicking, retro = retrospective, pros = prospective, VME = vertical maxillary excess, norm/low/high angle = mandibular plane angle definitions, skel = skeletal, vert = vertical, mand = mandibular, progn = prognathia. \*measured by Helkimo's DIII and DIIII

#### ***2.4.4 Masticatory performance and malocclusion***

Many of the orthognathic surgery patients may, before their treatment, exhibit masticatory performance and occlusal characteristics that differ from those seen in a normal population, including a decreased number and intensity of occlusal contacts and malocclusions with frequent interferences (Athanasίου *et al.* 1989b). Masticatory efficiency has been investigated in relation to occlusion, and a significant correlation has been reported. Patients with malocclusions have been shown to have reduced masticatory efficiency. (Luke & Lukas 1985, Kikuta *et al.* 1994). Masticatory efficiency may be related to many different factors, including the number of teeth present, the number of occluding tooth pairs, the occlusal contact area, the actions of soft tissues and the preferred chewing side (Magnusson T *et al.* 1990). Luke & Lukas (1985) found that even relatively minor variations from normal or ideal intercuspation in the buccal segments may reduce chewing efficiency. Electromyographic (EMG) studies of subjects with various dentofacial morphologies have provided support for the assumed association between muscle structure and function and skeletal malocclusion (Ingervall & Thilander 1974, Proffit *et al.* 1983, Dean *et al.* 1992). Individuals with vertical maxillary excess (long face) tended to have decreased EMG activity, whereas persons with a vertically short maxilla showed increased EMG activity compared to subjects with normal facial morphology. On the other hand, several factors may influence the generation of maximal occlusal force, including the size of the muscles, the distribution of different types of muscle fibers, the activity level of the muscles, the sensitivity of the teeth and the muscles and TMJ and the patient's willingness to exert maximal force. (Ingervall & Thilander 1974, Proffit *et al.* 1989).

Alteration of the facial skeleton by means of orthognathic surgery may produce significant changes in the mechanical advantage of the masticatory muscles and also physiologically by altering the sensory and proprioceptive inputs (Proffit *et al.* 1989, Harper *et al.* 1997). A noticeable tendency towards normalization in the masticatory patterns has been recorded after orthognathic correction of severe Class II and Class III malocclusion (Ehmer & Broll 1992). Myofascial facial pain patients with more severe pain intensity are likely to reduce their intake of dietary fiber (Raphael *et al.* 2002). This is possibly due to an effort to decrease masticatory activity to avoid exacerbating facial pain and may increase the risk of constipation.

As a summary, research has provided evidence that masticatory forces and functional patterns in patients with dentofacial malocclusions are different from those in the normal population, but only a few studies have reported presurgical and long-term postsurgical follow-up data on functional alterations.

## 2.5 Complications and adverse effects of orthognathic surgery

### 2.5.1 Nerve injuries

Nerve injuries in orthognathic surgery can be caused by indirect trauma, such as compression by surgical edema, or direct trauma, such as compression, tear or cut with surgical instruments or stretching during manipulation of the osteotomized bone segments (Ylikontiola 2002). Seddon (1943) classified neurosensory and motor deficits into three categories to characterize the morphophysiological types of mechanical nerve injuries: neuropraxia, axonotmesis and neurotmesis.

Neuropraxia is the mildest form of injury, and it is described as slight localized myelin sheath damage without continuity defect. The majority of inferior alveolar nerve (IAN) injuries following bilateral sagittal split osteotomy of the mandible (BSSO) are neuropraxias and may be due to nerve manipulation, traction or compression. Normal sensation or function is usually recovered within two months.

Axonotmesis is characterized by disruption and damage to axons and the myelin sheath without disruption of the perineurium or epineurium. This is due to greater or more prolonged injurious forces, and a longer and more profound neurosensory deficit follows than in neuropraxia.

Neurotmesis is a severe disruption of the nerve trunk, which may cause a profound and possibly permanent neurosensory deficit.

The incidence of neurosensory deficits in IAN after BSSO has been reported to vary from 0% to 85%. This wide range of incidence may reflect the variation in the number of subjects in the study groups, the follow-up times and the sensibility testing methods. (Westermark 1999). Several factors have been proposed to predispose neurosensory injury to IAN: the patient's age; the surgeon's skills; the magnitude of mandibular movement; additional genioplasty; and the degree of manipulation of the IAN (Westermark 1999, Ylikontiola 2002, Van Sickels *et al.* 2002). Even after perfectly performed sagittal splitting, there may sometimes occur sensibility disturbances, which have been proposed to be caused by manipulation of the IAN during the soft tissue dissection in the initial phase of BSSO (Jones & Wolford 1990, Jääskeläinen *et al.* 1995, Westermark 1999). Due to the common use of BSSO, further studies to develop the dissection techniques are indicated.

Reports on lingual nerve (LN) sensory deficits are fewer than reports on IAN sensory disturbances. The initial postoperative incidence has varied from 1% to 19% (Schendel & Epker 1980, Jacks *et al.* 1998), but according to most reports, the sensory deficit of LN tends to resolve over time. The proposed mechanism of injury to the LN appears to be associated with the fixation methods, either bone screws or wires, or with medial side tissue retraction.

Facial nerve injuries in orthognathic surgery are rare, but the consequences of such injuries may be devastating to the patient. Damage to the marginal mandibular branch of the facial nerve is a well-known complication of extraoral approaches to the mandibular ramus or angulus, but these approaches in current orthognathic surgery are rare. The facial nerve has been reported to be damaged in intraoral vertical subcondylar osteotomy

and in BSSO setback procedures with an incidence of less than 1%. The presumed trauma mechanisms have been compression caused by retractors behind the posterior ramus, fracture of the styloid process and direct pressure as a result of distal segment setback. Prognosis is good in incomplete loss of function, but poor if the loss of function is immediate and complete. (Jones & Van Sickels 1991).

Neurosensory impairment in the greater palatine and infraorbital nerves may be encountered after maxillary osteotomies. The incidence of prolonged sensitivity disturbances has been reported to be less than 4%, and they do not seem to bother the patients (De Jongh *et al.* 1986, Karas *et al.* 1990, De Mol van Otterloo *et al.* 1991).

### ***2.5.2 Complications in TMJ***

TMJ fibrous ankylosis or hypomobility following orthognathic surgery has been proposed to be caused by several factors: immobilization of the TMJ by intermaxillary fixation (IMF) (Ellis & Hinton 1991), iatrogenic displacement of the condyle posteriorly and intra-articular hematoma (Nitzan & Dolwick 1989) or excessive stripping of the periosteum and muscle attachments in the ascending ramus, resulting in scar contraction and myofibrotic tissue formation (Storum & Bell 1984). Fibrillation and erosion of condylar cartilage may be consequences of these factors, resulting in hypomobility or even condylar resorption.

Idiopathic progressive condylar resorption is a rare condition that has been considered to be caused by factors that diminish the normal functional remodeling capacity (age, systemic illnesses, hormones) or increase the biomechanical stress on the TMJ (occlusal therapy, internal derangement, parafunction, macrotrauma, unstable occlusion). As a consequence of these, a decreased condylar head volume, ramus height, growth rate (juvenile), progressive mandibular retrusion or apertognathia and a limited mandibular range of motion may occur. (Arnett *et al.* 1996a). The incidence of idiopathic condylar resorption is unknown. Arnett and Tamborello (1990) found 10 cases (1.2%) of condylar resorption in a population of approximately 800 dentofacial deformities examined over a 10-year period.

Condylar resorption has been associated with orthognathic surgery. Several risk factors have been proposed. Preoperative morphological or functional factors include radiological signs of osteoarthritis, TMJ dysfunction, condyles with a posterior inclination, a high mandibular plane angle and a low posterior-to-anterior facial height ratio (Kerstens *et al.* 1990, Moore *et al.* 1991, Merx & van Damme 1994, Bouwman *et al.* 1994, Arnett *et al.* 1996a,b, Hoppenreijns *et al.* 1998, Hwang *et al.* 2000). Contributing surgical factors include major mandibular advancement, counterclockwise rotation of the mandibular proximal fragment, IMF, rigid internal fixation, bimaxillary osteotomies and avascular necrosis of the condyle (Schellas *et al.* 1989, Kerstens *et al.* 1990, Moore *et al.* 1991, Merx & van Damme 1994, Bouwman *et al.* 1994, Cutbirth *et al.* 1998, Hoppenreijns *et al.* 1998). Young females (15–30) have a higher risk for condylar resorption than males and older females (Kerstens *et al.* 1990, Moore *et al.* 1991, Merx & van Damme 1994, Arnett *et al.* 1996a,b, Hoppenreijns *et al.* 1998). The incidence of

postoperative condylar resorption has been reported to vary from 1% to 31%. This is probably partly due to the great variation in the study populations (Kerstens *et al.* 1990, Moore *et al.* 1991, Bouwman *et al.* 1994, De Clercq *et al.* 1994).

### ***2.5.3 Vascular complications***

Uncontrolled hemorrhage in the jaws may result from either a mechanical disruption of blood vessels or congenital or acquired coagulopathy (Christiansen & Soudah 1993). The most common cause of hemorrhage in association with orthognathic surgery is a lack of surgical hemostasis (Lanigan *et al.* 1990a, 1991a). Variations in the bony or vascular anatomy or inadvertant handling of tissues with normal anatomy, hypotensive anesthesia or infection may be causes of immediate or secondary hemorrhages. If major hemorrhage can be avoided, recovery is quicker (Neuwirth *et al.* 1992).

Maxillary osteotomies, especially LeFort I and II osteotomies, have the potential for the most serious bleeding sequelae in orthognathic surgery. These complications may present as immediate intraoperative bleeding or as postoperative swelling or epistaxis. The most common sources of hemorrhage are the terminal branches of the internal maxillary artery, especially the descending palatine or sphenopalatine arteries. Bleeding from these may be caused by a curved osteotome, drilling, an oscillating saw or downfracture of the maxilla. The downfracture may even damage the internal carotid artery, if a basal skull fracture ensues that involves areas such as the foramen lacerum and the carotid canal. Even arterio-venous fistulas are possible. (Lanigan 1988, Lanigan *et al.* 1990a, 1991b, Mehra *et al.* 1999).

Most bleeding associated with mandibular osteotomies tends to be intraoperative and occurs rarely compared to maxillary osteotomies (Lanigan *et al.* 1991a). If the soft tissues are retracted properly to allow the operation to be done completely in a periosteal envelope, the risk for significant hemorrhage is small.

Severe, prolonged disturbances in blood circulation may lead to avascular tissue necrosis, which may cause tooth devitalization, periodontal defects or even loss of major bone segments. Due to the dense network of anastomoses in the face, this is a rare event, but may manifest both in the maxilla and in the mandible, especially in association with segmental osteotomies. The anterior part of the maxilla is a special risk zone. (Epker 1984, Lanigan *et al.* 1990b, Lanigan & West 1990, Lanigan 1995). Although, in animal studies, preservation of the descending palatine artery was not found to be critical for maintaining blood flow to the downfractured maxilla (Bell *et al.* 1975, 1995), Lanigan *et al.* (1990b) recommended that the artery should be preserved whenever possible and the segmentalization of the maxilla should be minimized. A wide, intact soft tissue pedicle is important for the circulation of the downfractured maxilla. In the mandible, avascular necrosis can be largely avoided by minimal stripping of the mucoperiosteum and muscle attachments (Bell & Schendel 1977).

### **2.5.4 Relapse**

Relapse is an unpredictable risk of orthognathic surgery. Many of the studies reporting relapse have limitations of sample size or the duration of follow-up, involve different surgical techniques being applied in the same sample or suffer from limitations in the application of cephalometric measurements. Relapse may be dental or skeletal or both.

In general, mandibular advancement appears to be stable, if rigid internal fixation is used (Van Sickels & Richardson 1996, Dolce *et al.* 2000, 2002) and if anterior facial height is maintained or increased (Proffit *et al.* 1996). Several factors may affect relapse in mandibular advancements: the surgeon's skills; proximal segment control, including condylar positioning and prevention of proximal segment rotation; prevention of counterclockwise rotation of the distal segment in cases with a high mandibular plane angle; the degree of mandibular advancement; and stretching of the perimandibular tissues, including skin, connective tissues, muscles and periosteum. (Will *et al.* 1984, Smith *et al.* 1985, Phillips *et al.* 1989, Moenning *et al.* 1990).

Mandibular setback is not always stable, and the inclination of the ramus at surgery appears to have an important influence on stability (Proffit *et al.* 1996)

The stability of maxillary osteotomies is affected by the magnitude of the anterior movement and the magnitude of the inferior repositioning of the maxilla, the adequacy of mobilization of the downfractured maxilla at surgery, the extent of bone contact in the newly established position of the maxilla and the type of fixation (Proffit *et al.* 1991a,b, 1996, Baker *et al.* 1992). Louis *et al.* (1993), on the other hand, did not find any correlation between relapse and the magnitude of maxillary advancement. The most stable maxillary procedure is superior repositioning, and forward movement is also reasonably stable. Inferior repositioning is less stable, especially if it causes downward rotation of the mandible and stretching of the elevator muscles of the jaw. The least stable orthognathic procedure is transverse expansion of the maxilla. (Proffit *et al.* 1996).

### **2.5.5 Infection**

Infection after orthognathic surgery may be acute or chronic, local or general. Most postoperative infections are caused by endogenous bacteria, most likely aerobic streptococci (Peterson 1990). Infection is initiated if the equilibrium between the host's defence system and bacterial virulence is lost. Factors contributing to this in orthognathic surgery populations may be the usage of steroids, the duration of the surgical procedure, the patient's age, interference with the blood supply to the bony segments, dehydration of the wounds, presence of foreign bodies or sequestrum, hospitalization in large wards, nutrition, hematomas and smoking. The surgeon's experience, a good aseptic technique and gentle tissue handling are also relevant factors. (Peterson 1990).

In the classical wound cleanliness classification, normal orthognathic surgery wounds fall into the Class II category (Clean Contaminated Wound). An infection rate of 10% to 15% can be expected without use of antibiotics, in comparison to Class III with an

expected infection rate of 20% to 30%. In a Clean Wound (Class I), the probability of infection is approximately 2%. (Peterson 1990).

Studies dealing with infection after mandibular osteotomies report infection rates ranging from 0% to 18% (White *et al.* 1969, Guernsey & DeChamplain 1971, Willmar *et al.* 1979, Martis & Karabouta 1984, Buckley *et al.* 1989). In maxillary osteotomies, infection rates lower than 6% are mostly reported (Kufner 1971, Perko 1972, Kahnberg & Enström 1987), but in the study of Zijdeveld *et al.* (1999), a 52.6 % infection rate was found in a placebo medication group with bimaxillary surgery.

There is some controversy concerning the need for prophylactic antibiotics (Peterson 1990, Martis & Karabouta 1984, Zijdeveld *et al.* 1999), and many different practices exist. The operator must assess dosage, timing, duration of therapy and side-effects when considering antibiotic prophylaxis. Peterson (1990) has outlined the following principles for rational use of antibiotic prophylaxis in orthognathic surgery: (1) the surgical procedure should involve a significant risk for infection. Wound Cleanness Class II includes an increased risk for infection (10–15%), as do bone grafts; (2) correct antibiotics should be selected; (3) the antibiotic level should be high; (4) the antibiotic must be administered in a correct time sequence; (5) the shortest effective antibiotic exposure should be used.

### **2.5.6 Other complications**

Fractures of the osteotomized segments in BSSO, i.e. bad splits, have been reported to occur in 3% to 23% of cases (Van Merkesteyn *et al.* 1987, Ylikontiola 2002). Ophthalmic complications are rare sequels of maxillary osteotomies. They include decreased visual acuity, extraocular muscle dysfunction, neuroparalytic keratitis and nasolacrimal problems (Lanigan *et al.* 1993). These injuries appear to be caused by indirect trauma to the neurovascular structures during the pterygo-maxillary dysjunction or fractures extending to the base of the skull.

Other anecdotal problems, such as endotracheal tube damage (Thyne *et al.* 1992), tympanometric changes (Baddour *et al.* 1981) and prolonged dysphagia (Nagler *et al.* 1996), have been reported. Even life-threatening events may occur (Edwards *et al.* 1986).

Periodontal problems and tooth damage may be encountered, especially in segmental osteotomies. Problems are probably mostly caused by errors in the surgical technique. The design of the soft tissue incisions is critical: vertical incisions in the area of osteotomy will predictably create periodontal problems. Trauma to the palatal mucoperiosteum is a risk. Excessive heat generation with oscillating or rotating instruments, soft tissue injury or excessive interdental bone removal may result in compromised vascular supply to the area, as does also marked repositioning of the segment. Poor oral hygiene plays some role in periodontal problems. Many of the surgical problems can be minimized if an interdental space is created preoperatively by orthodontic means. (Wolford 1998).

## 2.6 Costs of orthognathic surgery

Little has been written about the costs of orthognathic surgery, although continuously growing expenditure poses serious challenges to the current health economy and medicine in all fields. Dolan *et al.* (1987) analyzed the hospital charges for orthognathic surgery, focusing on the surgical phase. Later, Lombardo *et al.* (1994) and Dolan & White (1996) made comparisons of different costs using the results of the previous study by Dolan *et al.* (1987) as reference. They found, for example, that the time spent in hospital had decreased significantly during a few years. They concluded this to be due to the introduction and use of the internal rigid fixation method, which, on the other hand, increased the expenses of orthognathic surgery. Permert *et al.* (1998) presented cost data from orthodontic treatment in the Public Dental Service in Sweden. Orthodontics with removable appliances performed in general dental practices included an average of 8 visits and cost approximately 1000 US dollars. If the treatment turned out to be complicated, the patient was referred to a specialist clinic. There does not, however, seem to be any comprehensive report of the costs and cost factors of the whole process of orthognathic surgery.

### **3 Aims of the study**

This study aimed at a comprehensive assessment of the psychosocial and biophysiologic indications for orthognathic surgery as well as an evaluation of the psychosocial and functional outcomes of the treatment. The more specific aim was to define the kinds of patients with dentofacial deformities who benefit most from orthognathic surgery and the costs and risks at which possible benefits are attained.

The specific aims of the study were to

1. determine in a standardized way patients` motives for seeking orthognathic surgery, to identify presurgical symptoms and problems and to investigate patients` reactions to surgery.
2. examine the influence of orthognathic surgery on the functional status of the masticatory organ. Do some types of dentofacial deformities benefit from treatment more than others?
3. assess the incidence of various problems and complications in orthognathic surgery and to test the influence of a special instrumentation technique to protect the inferior alveolar nerve bundle in the initial soft tissue dissection phase of sagittal split osteotomy.
4. analyze the cost-effectiveness of orthognathic surgery in relation to specific dentofacial deformities and to explore the cost factors possibly influencing the expenses.

## **4 Material and Methods**

### **4.1 Patients**

The present study series consisted of patients referred for evaluation and treatment of their dentofacial deformities to the Clinics of Oral and Maxillofacial Surgery of Vaasa, Seinäjoki or Turku, Finland. For the prospective Papers I, II and IV, patients were collected consecutively. Basically, all patients referred during a given period were included, with the exceptions shown in demographic data in Table 2. Most of these study patients (159 /199) were operated on in Vaasa Central Hospital. All of these patients had preoperative orthodontics.

In the retrospective Papers III and V, the patient files and radiographs of orthognathic patients operated on in Vaasa constituted the material, as also shown in Table 2. Some of the patients covered in Paper III did not need active orthodontic treatment. Paper III showed 88.6 % of the 655 patients to be healthy, while 2.6% had cardiovascular disease, 2.3% had a respiratory disorder, 1.2% had a gastrointestinal disease and 5.3% had some other disorder, such as a connective tissue disease or a musculoskeletal or endocrinologic disorder. Notes on complications and problems were gathered from the patient files and radiographs. Adequate pre- and postoperative radiographs (panoramic radiographs or lateral cephalograms) were available for 559 patients, whereas 20 preoperative and 54 postoperative radiographs were missing, and neither pre- nor postoperative radiographs were available for 22 patients.

The clinical diagnoses covered in the present study are shown in summary in Table 3. The majority of patients had mandibular hypoplasia, and the most common surgical operation was BSSO with advancement (Table 4). Genioplasty was hardly ever done as a separate procedure

*Table 2. Number, age and gender of patients, criteria for patient selection.*

No. and type of original paper	No. of patients	Mean age (range, years)	Gender (F/M)	Inclusion criteria	Excluded/ drop-outs
I Prospective	100	31 (17–55)	71/29	Consecutive between May 1994 and May 1995	1 lost to follow-up, 1 re-operated, 2 filled questionnaire improperly
II Prospective, controlled	60 (st) 20 (c)	33.2 (16–56) 31.5 (15–44)	49/11 16/4	Consecutive between 1993 and 1995 No treatment at all (c)	2 had orthodontics only, 1 could not be reached, 1 had neurolomuscular and one had psychiatric disorder (st). Pts with occlusal grinding or splint therapy (c)
III Retrospect.	655	30.3 (15–60)	475/180	Operated on in VCH between 1983 and 1996	–
IV Prospective, controlled by contralateral surgical site	39	38 (18–60)	28/11	Consecutive BSSOs with/without maxillary surgery	Pts with GP or other concomitant mandibular surgery or pts with only maxillary surgery
V Retrospect.	99	38.3 (18–64)	61/38	Operations and orthodontics in VCH, good quality radiographs available	Orthodontics elsewhere, pts with poor quality radiographs, pts with re-operation, major bone grafts or complications

Abbreviations: st = study group, c = control group, pts = patients, BSSO = bilateral sagittal split osteotomy, GP = genioplasty, VCH = Vaasa Central Hospital, retrospect. = retrospective

*Table 3. Clinical diagnoses of patients in various Papers of the present study. Paper II: scores of control group in parentheses.*

Diagnosis	Paper					Total	% of all diagnoses
	I	II	III	IV*	V*		
Mandibular hypoplasia	75	40 (16)	364	29	60	568	60%
Mandibular hyperplasia	4	5	38	1	4	52	5%
Maxillary hypoplasia	2	1	55		10	68	7%
Mandibular and maxillary hypoplasia		2	12	1	4	19	2%
Anterior open bite	7		22	1	3	33	3%
Anterior open bite with mandibular hypoplasia or hyperplasia	9	9 (4)	18	5	8	49	5%
Anterior open bite with maxillary hyperplasia (VME) or hypoplasia		3				3	< 1%
Asymmetry, mandibular	3		22	1	2	28	3%
Maxillary hyperplasia			2			2	< 1%
Other deficit in both jaws			61		3	64	7%
Dentoalveolar malposition			5			5	< 1%
Other (various combinations of the above)			51	1	5	57	6%
Missing			5			5	< 1%
TOTAL	100	60 (20)	655	39	99	953	100

Abbreviation: VME = vertical maxillary excess \*Selected patient material

*Table 4. Surgical operations performed on the patients in various Papers of the present study. Several patients have had more than one procedure.*

Type of operation	Paper					Total
	I	II	III	IV	V	
BSSO advancement	76	40	445	38	65	657
BSSO set back	4	2	70	1	3	79
Genioplasty	15	5	97		7	124
LeFort I osteotomy	6	3	146	6	12	173
Bimaxillary	14	15	81*	8*	13	131
Mandibular segment osteotomies			56		7	63
Maxillary segment osteotomies			19	2		21
SARME			28			28
Other			4			4

Abbreviations: BSSO: Bilateral sagittal split osteotomy SARME: Surgically assisted rapid maxillary expansion

\*Osteotomies of each jaw are also included in single-jaw osteotomy scores

## 4.2 Methods

### 4.2.1 Psychological considerations in orthognathic surgery

The study intended to determine patients' motives in seeking orthognathic surgery, to identify presurgical symptoms and problems and to ascertain their reactions to surgery and their satisfaction with life before and after surgery (paper I). Information about the patients' perception of symptoms and problems before and after surgery, about their motives for seeking orthognathic surgery, and the influence of treatment on these factors was collected by means of structured questions with ranked responses or set alternatives. In the postsurgical assessment, visual analogue scales (VAS) were used to measure the patients' satisfaction with the results. The patients were also inquired about any possible complications following surgery. The questionnaire used was largely based on that used in previous studies (Kiyak & Bell 1991, Ostler & Kiyak 1991). The questionnaire was also chosen in order to enable more reliable statistical handling: the interview, whether structured or free, is known to be influenced by the interviewer. The patient's psychosocial well-being was measured using a life satisfaction questionnaire, in which various aspects were assessed on a 7-point scale (1 = extremely dissatisfied, 7 = extremely satisfied).

#### ***4.2.2 Effects of orthognathic surgery on TMD and masticatory function***

The present study aimed to clarify the controversial association between the effects of orthognathic surgery and TMD using a case-controlled, prospective clinical follow-up design (paper II). Signs and symptoms of TMD and occlusal parameters (overjet, overbite, maximal mouth opening, deviation at mouth opening, lateral and protrusive movements, horizontal and lateral glide in retruded contact position and intercuspal position, mediotrusive and laterotrusive interferences, number of occluding pairs of teeth, pain when moving the jaw, palpation and auscultation of the TMJs and palpation of the masticatory muscles) were assessed three times in the study group of 60 patients: (1) before orthodontic treatment, (2) approximately 12 months postoperatively (range 9–16 months), when active orthodontic treatment had been discontinued, (3) approximately 29 months postoperatively (range 20–44 months). The control group of 20 patients consisted of subjects who were seeking treatment for similar dentofacial deformities, but who did not wish to have treatment after the examinations and the information given at the first visit. They were examined twice during the investigation: (1) at the first visit and (2) approximately 52 months later (range 33–70 months).

Each control visit included a written anamnestic questionnaire and a clinical and radiological examination, but because some subjects in the control group refused radiography at the final visit, no radiological comparison could be made in the control group. The basic data from the questionnaire and the clinical examination were calculated and classified according to Helkimo's Anamnestic Index (Ai) (graded on a scale of Ai0 = no subjective symptoms, AiI = mild subjective symptoms and AiII = severe subjective symptoms) and Dysfunction Index (Di) (Di0 = no symptoms, DiI = slight symptoms, DiII = moderate symptoms, DiIII = severe symptoms) (Helkimo 1974). The radiological examination included visual assessment of condylar morphology from panoramic tomographies and mandibular plane angle (Sella-Nasion-Menton-Gonion, SN-MeGo) from lateral cephalograms. The possible association of this angle with TMD was analysed. The frequency of headaches was recorded on the following scale: (1) once or twice a month, (2) once or twice a week, (3) more than once or twice a week, (4) "migraine type": symptoms suggestive of genuine migraine, but definitive diagnosis not yet made by a neurologist. Some patients did not report headache at all or had headache less often than once a month.

#### ***4.2.3 Complications and adverse effects of orthognathic surgery***

The purpose of the study was also to determine the incidence of a variety of complications and problems reported in several earlier studies, many of which are case reports. The incidence of pre-, intra- and postoperative complications were evaluated retrospectively based on the criteria proposed by Dimitroulis (1998) (paper III). Complaints about the treatment addressed to the Patient Insurance Center (PIC) of Finland between 1990 and 1999 were also gathered from the statistics of PIC. PIC is a

national authority to which a patient can appeal if s/he is dissatisfied with the treatment without a need for a law suit.

Complications and problems occurring at three phases of treatment were recorded. Notes related to information, orthodontics, TMJs and attitudes towards the treatment were regarded as preoperative complications. Intraoperative complications consisted of such problems as hemorrhage, visible nerve injuries, unfavourable osteotomies, jaw malpositioning, technical or instrument failures, drug reactions and other adverse consequences that occurred during the patient's stay in hospital. Complications that appeared later were classified as postoperative. These included remarks on neurosensory disturbances in the anatomical regions innervated by the inferior alveolar nerve and the lingual, infraorbital and facial nerves, secondary gross swelling or late bleeding, reoperations, malpositions of the proximal fragment in BSSO, infections, unsatisfactory occlusal outcome, TMJ problems or other problems. Relapse of the treatment results was not specifically analyzed, because this issue has been quite thoroughly reported in the earlier literature. This would also have necessitated more standardized cephalograms, as the current quality and magnification varied far too much. General remarks about the stability of the treatment results or the relapse were, however, picked up from the files. Relapses were roughly classified as "mild" or "severe", with "severe" referring to cases in which, according to the files, the overall results were considered no better than before the treatment and there remained a need for a new treatment or a reoperation. The rest were classified as "mild". The Finnish Patient Insurance Centre (PIC) was contacted for information on official claims concerning orthognathic surgery addressed to the PIC.

The panoramic radiographs were examined for signs of condylar resorption, unfavourable positions of the osteotomized segments and resorption or iatrogenic damage of the roots of the teeth. From the lateral cephalograms, the SN-MeGo angle was measured and compared to 32°, to find out the possible association between this angle and condylar resorption.

The patients' motivations to seek treatment were also assessed in this study. These motivations were classified as functional (stiffness in the jaws, difficulties to open the mouth wide, damage to the teeth/gingiva, improvement of mastication, occlusion, TMJ function), pain-related (other than headache: pain in the jaw, neck, TMJ), esthetic (face, teeth) or recommendation by others.

A surgical approach was tested aiming at improving the instrumentation in attempts to prevent injury to the IAN in the soft tissue dissection phase of BSSO (paper IV). Thirty-nine patients were operated on with the BSSO technique introduced by Trauner and Obwegeser (1957) and modified by DalPont (1961) and Hunsuck (1968). The hypothesis was that extremely gentle and minimal soft tissue dissection medial to the ascending ramus would cause less trauma to the IAN around the foramen mandibularis and thus less neurosensory deficits. This soft tissue dissection in the ramus and protection of the IAN was carried out with two surgical instruments differing in size and shape. On a randomly selected test side, a delicate, only slightly curved Howarth elevator was inserted with extreme caution above the mandibular foramen of each patient to protect the IAN. On the contralateral control side, a broader channel retractor with about 90° curve at the tip was placed above the foramen to the posterior side of ramus. Drilling was used to perform the horizontal osteotomy on the test side and sawing with a reciprocating saw on the control side. It was thought that these instrumentations differed from each other in the degree of

tissue retraction and the risk of nerve damage (less retraction and damage on the test side). Other intraoperative factors were kept macroscopically similar on both sides, and if nerve damage or some other complication was assumed to have occurred during the osteotomy, the patient was excluded from the study.

The neurosensory testing was carried out on both the test and the control sides using 2-point discrimination (2-PD) and the Vitality Scanner Test (VST) preoperatively and four times postoperatively up to approximately one year. In addition to these tests, the patients' subjective sensation on both sides was inquired.

#### **4.2.4 Costs**

As there do not exist publications assessing the costs of the entire process of surgical-orthodontic treatment, the purpose of the present study was to evaluate the expenses in the different phases of treatment in a community hospital (paper V). In particular, the aim was to find out the most costly phase of the treatment and the most expensive and cheapest types of malocclusion and mode of surgery as well as to identify the specific clinical or cephalometric factors influencing costs.

Firstly, cost data were gathered from four phases of the orthognathic surgery process: (1) pre- and postoperative orthodontics in the Clinic of Orthodontics, (2) pre- and postoperative outpatient expenses in the Clinic of Oral and Maxillofacial Surgery (OMFS), (3) surgical operation, (4) inpatient period. The proportion of total costs allocated specifically to surgical-orthodontic treatment was calculated on the basis of the annual number of visits for surgical-orthodontic treatment in both clinics. These visits were classified into 4 (orthodontics) and 6 (OMFS) cost categories. With the help of the patient files, the number of individual visits was multiplied by the price of each visit, which yielded the individual outpatient costs in each clinic. The costs for each surgical operation were obtained by utilizing the general activity-based cost (ABC) analysis that had been done for Central Operating and Recovery Units. The inpatient period costs were calculated using the day-based invoices sent to municipalities.

Secondly, the total costs and expenses in each phase were tested and analyzed in view of the patient's age, various occlusal and clinical factors as well as the clinical and skeletal diagnosis. Computerized skeletal analysis was performed by digitalizing and assessing the pretreatment and early retention phase cephalograms with the RMO-Joe software (Rocky Mountain Company) in order to identify the skeletal features possibly influencing the difficulty and costs of treatment.

### **4.3 Statistics**

Wilcoxon signed-rank test was used as follows: to assess the significance of changes in reported symptoms and problems and satisfaction with life before and after surgery in paper I; to assess the difference between various preoperative and postoperative

anamnestic and clinical measures included in Helkimo's Anamnestic and Dysfunction indexes and occlusal parameters in paper II; in paper III, to assess the differences between the numbers of patients in the different categories of motivations to seek treatment and between the ages of patients with and without neurosensory disturbances; in paper IV, to assess the differences between the test and control sides in 2-PD and VST test scores at every control visit .

Spearman's correlation coefficient was used in paper I to assess the relationship of various factors with overall satisfaction and in paper II to study the association between  $A_i$  or  $D_i$  and the specific type or magnitude of dentofacial deformity, between  $A_i$  or  $D_i$  and the patient's age and between the occlusal parameters or  $A_i$  or  $D_i$  and the specific type of malocclusion. In paper III, Spearman's correlation coefficient was used to assess the relationship between the patient's age and the inpatient period or condylar resorption or TMD; in paper IV, to test the association between the subjective sensation and such variables as age, gender, 2-PD and VST; and in paper V, to test the differences between costs in various phases and the tested clinical and cephalometric values.

Wilcoxon's two-sample test was used in paper I to assess significance in relation to the categorical variables. In paper V, analysis of covariance (ANCOVA) was used to test the costs of orthodontics, surgery and inpatient care and total costs in relation to the different clinical and cephalometric values and measurements. The outpatient surgery clinic cost was tested first by using ANCOVA and then by applying a regression-type model, because none of the categorical variables were significant. The cost differences between the various diagnostic and operative groups were tested with analysis of variance and paired t-tests, and due to the multiple comparisons, a Bonferroni procedure to correct the p-values was added in paper V.

For paper IV, calibration of the two investigators for 2-PD was done, i.e. the inter-examiner difference was tested with non-operated volunteers by t-test and was found to be negligible.

## **5 Results**

### **5.1 Psychosocial profiles of patients**

The most common motive for seeking treatment was to improve occlusion (92%), followed by prevention or improvement of TMJ problems (70%), improvement of chewing ability (68%) and appearance of teeth (67%), as demonstrated in Table 5. These were also the aspects in which patients most often (91%–72%) reported improvements as a result of surgery. General health, self-esteem and improvement of facial appearance were less often mentioned as motives for seeking treatment (27%–46%) (Paper I). The results of the Papers II and III are in accordance with these findings: functional and/or pain-related problems constituted 61% and 52% of the motives, while cosmetic and functional/cosmetic motives together represented 28% and 20% of the motives. It was also shown that the patients with functional and pain-related reasons for seeking treatment were older (median 34 and 33 years, respectively) than the patients with cosmetic (median 27 years) and other reasons (Paper III).

*Table 5. Motives for seeking treatment and effects of treatment (n = 100)*

Motive for seeking treatment	Classification of motive*	Percentage of patients	Percentage of patients considering improvement achieved**
Improvement in chewing ability	O	68	82
Improvement in appearance of teeth	A	67	72
Improvement in occlusion	O	92	91
Prevention of tooth and periodontal disease	D	36	36
Improvement in facial appearance	A	39	46
Prevention or improvement of TMJ problems	O	70	74
Improvement in speaking ability	S	19	19
Improvement in work performance	S	14	9
Improvement in general health	S	31	27
Improvement in breathing	S	17	13
Improvement in self-esteem	S	20	29

\*Classification according to Ostler and Kiyak (1991): O = oral function; A = appearance; S = social health; D = disease prevention. \*\*Patients could also indicate if a particular motive had played no role in their decision to undergo surgery.

Problems relating to occlusion and mastication were rated as the most significant problems before surgery, and the next highest scores were allotted to temporomandibular joint problems and headache. Perceptions of the appearance of teeth and, to a lesser degree, facial appearance were also rated high. General appearance, speech and general health, self-esteem and social interactions were not considered particularly problematic by the patients. Significant improvements were noted after surgery in relation to all aspects except work performance and general health.

The scores for satisfaction with life were uniformly high before surgery, but even higher one year after surgery. Most differences between pre- and postoperative scores were significant (work, livelihood, personal relationships, leisure, mental health, health, concept of life). Overall satisfaction correlated with low numbers of postoperative problems ( $p < 0.0001$ ), especially TMJ problems ( $p < 0.0001$ ), facial appearance problems ( $p < 0.0001$ ), biting problems ( $p < 0.001$ ), problems with general health ( $p < 0.001$ ), occlusal problems ( $p < 0.01$ ) and problems with teeth and general appearance ( $p < 0.01$ ). Willingness to undergo surgery again was high, 8.6 (on a VAS scale from 0 to 10), and willingness to recommend surgery to others with similar problems was 9.0.

The duration of postoperative orthodontics had no effect on treatment satisfaction, but those reporting postoperative numbness of the lower lip and chin were less satisfied than those not reporting numbness ( $p < 0.01$ ). Thirty-one patients (33% of patients with mandibular surgery) reported numbness.

## 5.2 Effects of orthognathic surgery on TMD and masticatory function

Signs and symptoms of TMD were frequently seen throughout the follow-up of the orthognathic surgery population as shown in Table 6. At least one sign of TMD was present in 73% of the patients preoperatively, and at the last postoperative control visit, 60% of patients presented some sign of TMD ( $p = 0.01$ ), and the overall prevalence of various signs of TMD was reduced, as can be seen in Table 6. High preoperative prevalence (46%) and reduction of TMD (to 29%) were also seen in Paper III, but these data were gathered retrospectively. Six patients (10%) had reduced mouth opening ( $< 40$  mm) in the last control, but this had no clinical relevance to the patients.

Table 6. Numbers of patients with signs and symptoms of TMD in various examinations ( $n = 60$ ). In parentheses: control group,  $n = 20$ .

	Joint clicking	Joint crepitation	Joint pain on palpation	Muscle palpation tenderness*	Headache	Max. opening $< 40$ mm
Before treatment	25 (8)	13 (4)	27 (6)	30 (7)	38 (10)	0 (0)
One year after treatment	25 (-)	12 (-)	7 (-)	12 (-)	11 (-)	8 (-)
The latest examination	29 (8)	6 (4)	11 (11)	11 (5)	12 (10)	6 (0)
		$P = 0.09^{**}$	$P = 0.0003^{**}$	$P = 0.0005^{**}$	$P < 0.001^{**}$	$P = 0.313^{**}$

\*  $> 6$  muscles of 12 tender to palpation \*\* Wilcoxon ranked signed test, study group (between first and latest examination). No statistically significant changes seen in control group.

Tenderness of the masticatory muscles to palpation ( $p < 0.001$ ), joint pain on palpation ( $p < 0.001$ ) and the number of patients with headache ( $p < 0.001$ ) were reduced significantly from the preoperative level. At the initial examination, 38 patients (63%) reported suffering from recurrent headache, whereas only 15 patients (25%) did so at the final examination. The frequency of remaining headache was also reduced. There was no improvement in headache in the control group. In the initial assessment, 89% of the patients with recurrent headache fell into the clinical dysfunction classes DiII or DiIII, and the difference compared to the patients with no headache was almost significant,  $p = 0.058$ . Patients without headache had an average of 5.4 muscles (out of 12) tender to palpation, whereas patients with headache had an average of 7.0 muscles tender to palpation at the initial examination. At the latest examination, there were only 11 patients with more than 6 muscles tender to palpation. No association with diagnosis, Ai, Di, overlap or overjet was found, however.

Reduction was also noticed in crepitation, but this did not reach statistical significance. This change was greatest in the patients with skeletal Class I and Class III malocclusions. Clicking of the TMJ, on the other hand, showed even a slight increase, as did the number of patients with reduced maximal mouth opening. The control group was initially almost identical, with 75% having signs and symptoms of TMD, but in contrast to the study group, the frequency of TMD increased to 85% of the patients during follow-up.

A weak positive correlation ( $r_s = 0.27$ ,  $p = 0.04$ ) was found between the patient's age and Ai before treatment. Significant improvement was found in Ai ( $p < 0.0005$ ) between

the first and the latest examinations. The older group of patients (> 30years) benefited most from the treatment.

Di improved significantly ( $p < 0.001$ ) between the preoperative and final examinations, and even more markedly among females. In the control group, no changes in Ai or Di were observed.

No association could be found between Ai or Di and the specific type or magnitude of skeletal deformity either in sagittal or vertical assessments.

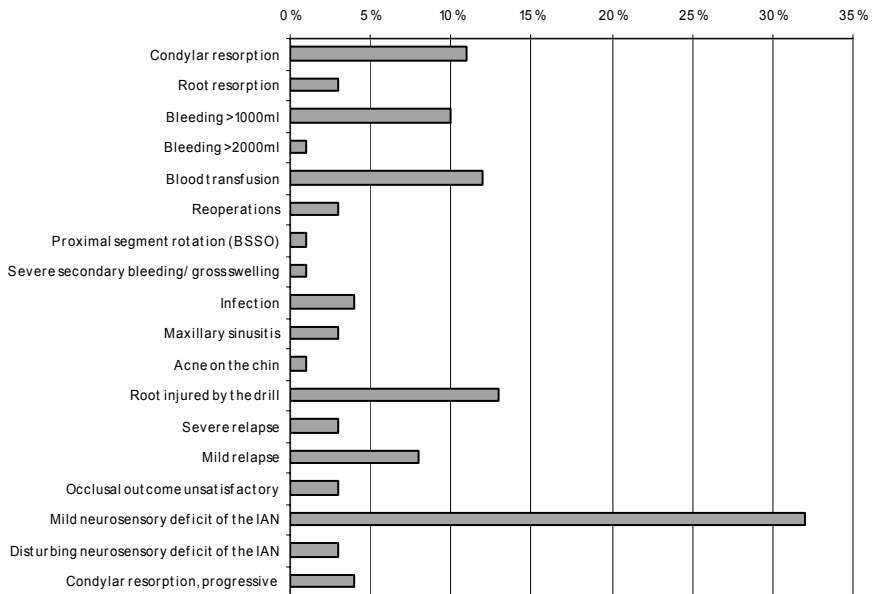
Four patients (6.7%) with no TMD before surgery developed signs of TMD during the postoperative follow-up. One patient in the study group and one in the control group underwent arthroscopy before the final examination. Resorption or condylar remodelling was present in six preoperative panoramic tomographies (10%), but no progressive changes during follow-up were observed.

All the parameters of occlusion showed significant improvement in the study group and seemed to remain stable during the observation period. In the control group, minor occlusal changes were seen in some individuals. No occlusal adjustments had been performed in these control subjects. The occlusal parameters were tested for relationships with Ai, Di and the specific type of malocclusion, but no significant correlation was found.

The significant reduction in recurrent headache was mostly already seen at one year postoperatively, and even those who continued to have headache reported a reduced frequency. Similar beneficial effects on recurrent headache after orthognathic surgery have also been reported by others (Magnusson *et al.* 1986, 1990, Wanman 1987, Smith *et al.* 1992, Le Bell *et al.* 1993). Most of the headache in the present study was considered to be of the muscle contraction type, and only 4 of the 38 patients had a common migraine type headache. The headache and non-headache groups differed almost significantly in tenderness of the masticatory muscle on palpation: the patients without headache had an average of 5.4 muscles (out of 12) tender to palpation, in comparison to 7.0 muscles in the headache group at the initial examination. The improvement in occlusion and masticatory muscle status associated with reduced headache coincides with the findings of Lous and Olesen (1982) and Forssell *et al.* (1985, 1986, 1987). There was no reduction in headache in the control group.

### 5.3 Complications and problems

*Preoperative phase.* Condylar resorption was seen in the panoramic tomographs of 58 patients (11%) preoperatively (Fig. 1). Symptomless root resorption of one or more of the teeth could be identified in 22 patients (3%). Two cases of condylar resorption were seen after preoperative orthodontics. There were no recordings of poor communication, incorrect diagnosis, poor dental laboratory work or defects in the patient's medical preparation and workup.



**Fig. 1. The incidence of most common complications and problems during orthognathic surgery between 1983 and 1996.**

*Intraoperative phase.* Excessive bleeding was the most common problem in the intraoperative phase, as shown in Fig. 1. More than 1000 ml of bleeding was seen in about 10% of patients, and more than 2000 ml in about 1% of patients; 12% of patients needed blood transfusions, but less than 1% of those with BSSO (average blood loss 340 ml), whereas every third patient needed blood transfusion during and after a bimaxillary operation (average blood loss 890 ml). The mean blood loss remained between 300 and 500 ml throughout the study period.

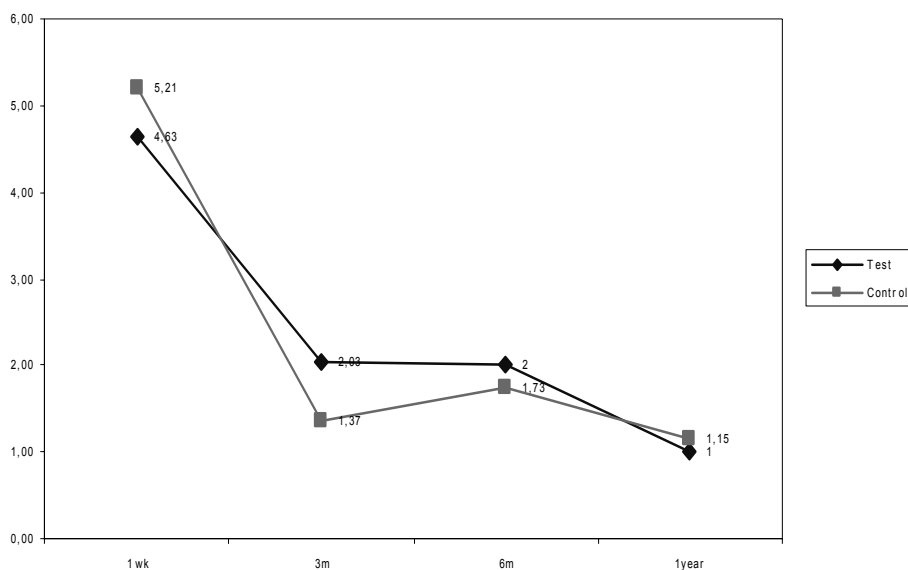
*Postoperative phase.* The incidence of most postoperative complications and problems is about 5% or less, with the exception of root injuries in segment osteotomies (13%), mild clinical relapse (8%) and neurosensory deficits of the IAN (32%), as shown in Fig. 1. The incidence of other problems was one or two cases of each. Progressive condylar resorption was observed in 28 cases (5%), 7 of whom had already had this problem preoperatively. Twenty one of these patients (75%) were operated with BSSO advancement, with or without genioplasty. Five of the patients had had bimaxillary surgery. In 63% of all condylar resorption cases, the SN-MeGo angle was greater than 32°, which would suggest a tendency towards skeletal open bite. No correlation was found between the patient's age and condylar resorption.

The most frequent complication was found to be neurosensory deficit of the IAN, which was mild in 32% and severe in 3% of the patients with osteotomy in the mandible. The patients with neurosensory deficit were older (mean, 33 years) than those with no disturbances (mean, 28.4 years,  $p < 0.01$ ). Only two patients reported disturbance of

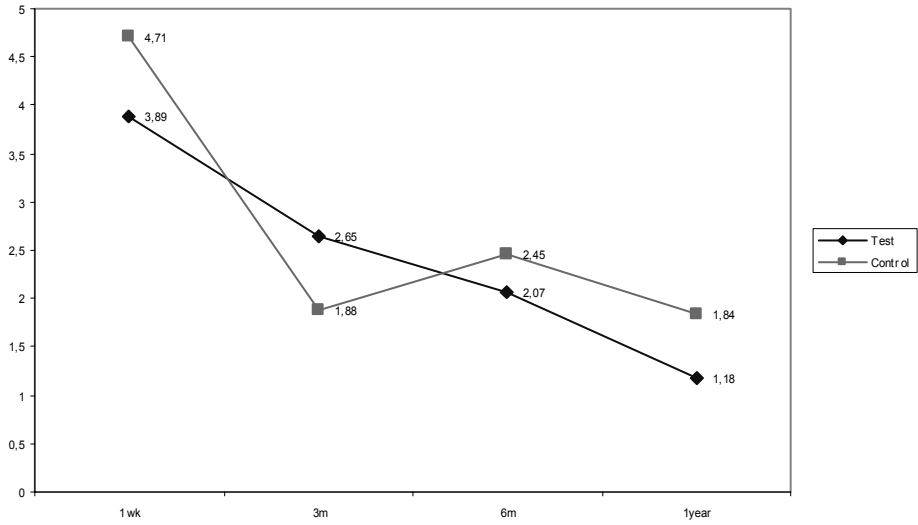
lingual nerve sensation, and 5 reported mild disturbance of infraorbital nerve sensation. There were no notes of disturbances of facial nerve function.

Prevention of the neurosensory deficits of the IAN with a special surgical instrumentation technique was tested (paper IV). At one week and one year, all the tests showed the neurosensory deficit to be slightly worse on the control side (channel retractor), although the difference was not statistically significant (Fig. 2, 3, 4). The figures show mean values, although the data were skewed towards the left, but they illustrate the trend. VST showed lower values on the test side (Howarth elevator) at all of the 4 control visits, and the difference at 6 months was also statistically significant ( $p = 0.028$ ) (Fig. 4). There were no differences in subjective sensation between the sides, but there was a correlation between subjective sensation and the 2-PD in the lower lip ( $p = 0.004$  at 6 months and  $0.038$  at one year).

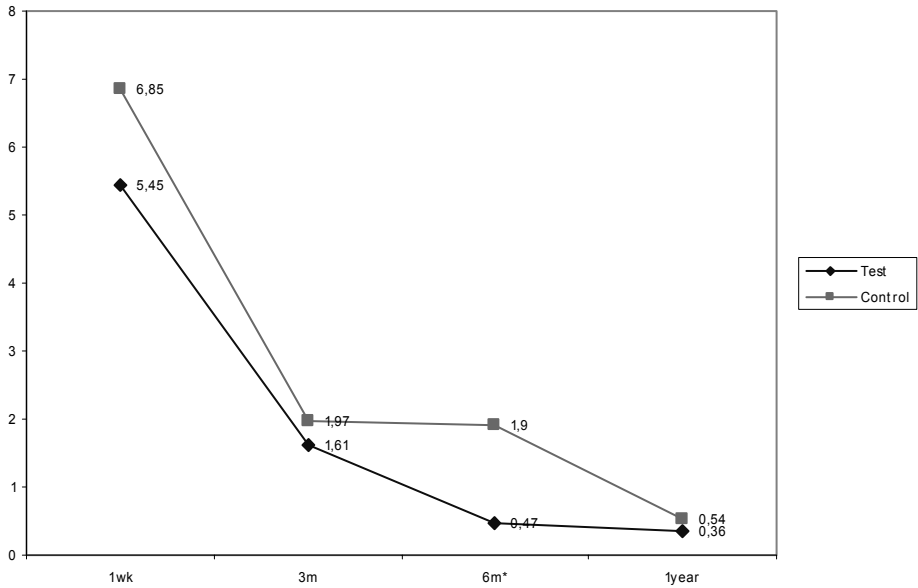
Both 2-PD and VST showed the maximum deviation from the preoperative test level (normal sensation) to occur at one week postoperatively, after which the sensation gradually normalized. Most patients had restored most sensation by the 3-month control visit, after which slower improvement towards the preoperative level continued. Subjective sensation followed the same trend. Five sides in both groups, i.e. 10 patients, and three patients with both sides continued to have slightly, but not disturbingly, altered sensation at one year. They account for 33% of the total study population. The mean age in this subpopulation was 43 years compared to the mean ages of 38 years in the whole group and 35.5 years in the group of patients with normal sensation,  $p = 0.05$ . None reported severe disturbance at this phase.



**Fig. 2. Deviation from presurgical measurements in two-point discrimination, lower lip (mm).**



**Fig. 3. Deviation from presurgical measurements in two-point discrimination, chin (mm).**



**Fig. 4. Deviation from presurgical measurements in Vitality Scanner Test \*p = 0.028.**

Age or gender had no influence on the measured neurosensory deficits on either the test or the control side. Subjective sensation had an almost significant correlation with gender at 6 months, but no longer at the one-year control visit.

While studying complications, the patients' motivation to seek treatment was also recorded, because it was thought to be potentially reflected in the overall satisfaction with the treatment and the alleviation of possible complications and side effects. There were 63 official claims concerning orthognathic surgery addressed to the PIC between 1990 and 1999, and the distribution of the types of claims is shown in Table 7.

*Table 7. The main reasons for claims concerning orthognathic surgery in Finland addressed to the Patient Insurance Centre (PIC) between 1990 and 1999.*

Complications	No. of claims
Compensation <i>paid</i> to the patient	
Unsuccessful operative outcome and/or need for reoperation	8
Nerve problem	3
Cosmetic reasons	2
Septum dislocation	2
Various others (one of each)	9
Compensation <i>not paid</i> to the patient	
Nerve injury	8
TMJ pain, other pain, or uncomfortable sensation in the face	10
Dissatisfaction with the outcome of the treatment	4
Various others	17
Total	63

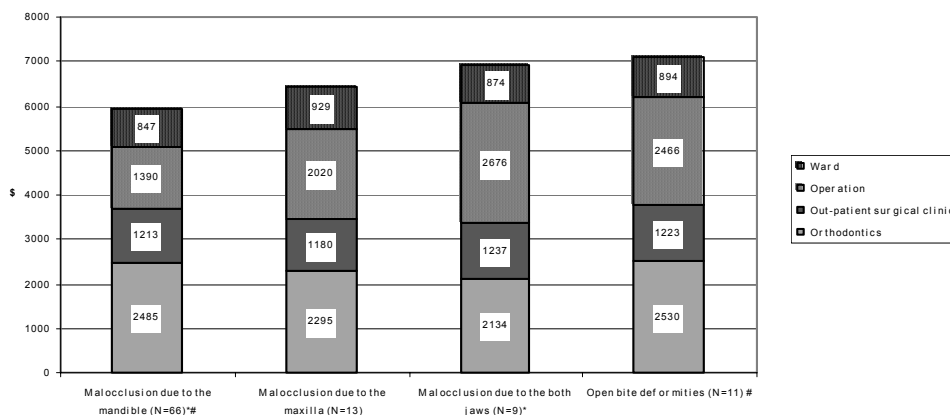
Data adapted from PIC, Helsinki, Finland.

## 5.4 Costs

An average of five surgical-orthodontic outpatient visits were made by each patient to the OMFS clinic (range 2–10). In the fiscal year 1999, the visits to the OMFS clinic for surgical-orthodontic treatment represented 16.7 % of the total number of visits. The costs of these visits made up 17.5 % of the total costs. The average number of visits per patient at the Clinic of Orthodontics was 26 (range 11–55), but only 24 patients made more than 30 visits, while one of them made more than 40 and one more than 50 visits. The majority of these 24 patients had skeletal discrepancies in the vertical dimension: eleven patients had skeletal open bite and nine had skeletal deep bite. Half of these patients had normal sagittal skeletal relations.

The average cost of routine surgical-orthodontic treatment was 6206 USD (Standard Deviation (SD)  $\pm$  912 USD), and the cost distribution of the different phases of treatment is shown in Fig. 5. Orthodontic treatment accounted for an average of 39% of the total, i.e. 2425 USD (SD  $\pm$  600 USD), followed by the surgical phase, which amounted to 28% of the total, i.e. 1708 USD (SD  $\pm$  627 USD). No correlation was seen between gender or age and costs. Space closure after tooth extraction raised the orthodontic costs compared to the non-extraction cases ( $p = 0.0015$ ). There was a positive correlation between the total outpatient costs and overbite (statistical significance,  $p = 0.04$ ) and a negative

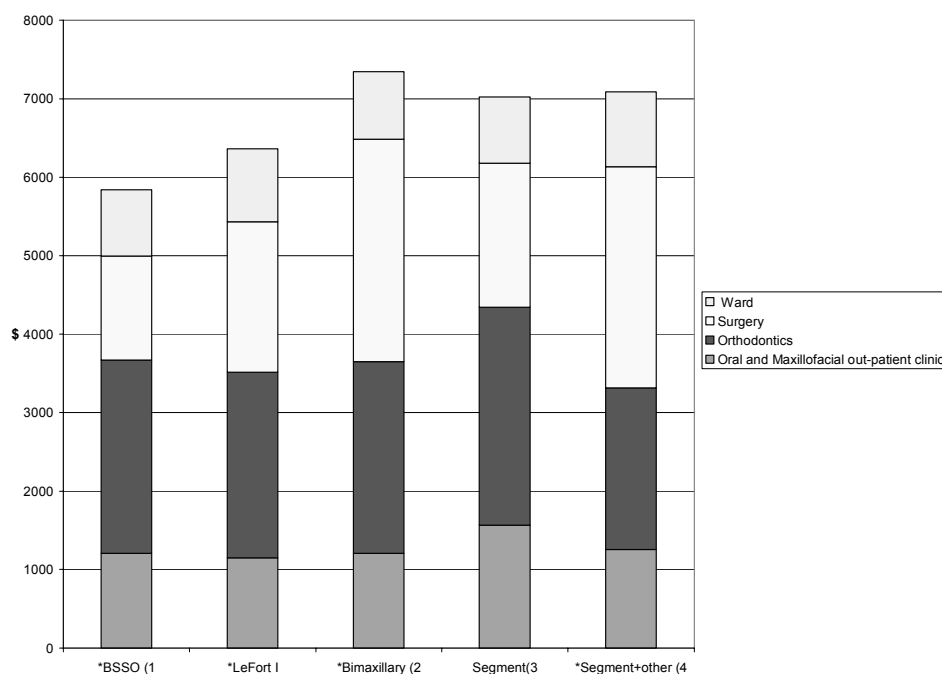
correlation between the total outpatient costs and lower facial height (statistical significance,  $p = 0.05$ ).



**Fig. 5. Costs of surgical-orthodontic treatment according to clinical diagnosis. \* and #: statistical difference  $p < 0.05$ .**

The mean total costs in the different diagnostic groups are shown in Fig. 5. A diagnosis of malocclusion due to the mandible resulted in the cheapest treatment, while open-bite deformity was the most expensive condition to treat. The cephalometric skeletal analysis also showed that the patients with open bite fell into the most expensive category, as did the Class III patients, although the differences were not statistically significant. The inpatient period was cheapest (847 USD) for malocclusions due to the mandible and most costly for malocclusions due to the maxilla (929 USD),  $p < 0.01$ . There were no other relevant correlations between the different test factors and costs.

When the data were assessed from the point of view of the performed operation, malocclusion treated with BSSO (advancement or setback with or without genioplasty) turned out to be the cheapest procedure (5870 USD) and bimaxillary operations (LeFort I osteotomy + BSSO with or without genioplasty) the most costly (7376 USD) (Fig. 6).



**Fig. 6. Costs according to the various operations. \*: statistical difference  $p < 0.05$ , (1 bilateral sagittal split ramus osteotomy with or without genioplasty, (2 BSSO + LeFort I with or without genioplasty, (3 anterior subapical segmental osteotomy of the mandible, (4 other = BSSO or LeFort I or genioplasty).**

Personnel costs, i.e. salaries, social security contributions and pensions, accounted for the major part of the surgical operation costs: 71% in bilateral sagittal ramus osteotomy (BSSO), 52% in LeFort I osteotomy and 65% in bimaxillary operation (LeFort I/BSSO). The material charges for rigid fixation accounted for less than 10% of the costs (58 USD in BSSO, 590 USD in LeFort I osteotomy, 648 USD in bimaxillary operation).

The average actual operation time was 83 min for BSSO, 97 min for LeFort I and 178 min for bimaxillary osteotomy. A remarkable proportion of the working time of the operating theatre team was spent outside the actual operation: 75 min in BSSO and 80 min in LeFort I osteotomy. This time was not recorded for bimaxillary osteotomies.

## **6 Discussion**

### **6.1 Methodological aspects**

The present study series consisted of patients referred to the specialist Clinics of Oral and Maxillofacial Surgery of Vaasa, Seinäjoki or Turku and together represent a population of over a million people in Western Finland. It is not a random sample of basic population, but could be regarded as representative of a subpopulation of patients with major dentofacial deformities. It should be borne in mind, however, that some distortion of the patient series may have been caused by the referral patterns of individual dentists or physicians and the patients' willingness to seek information and treatment. The strength of this patient series, on the other hand, lies in its racial and ethnic homogeneity, which means that cosmetic expectations, for example, are not influenced by this aspect.

This study shows that the majority (60%) of patients had a skeletal Class II deformity (usually mandibular hypoplasia/retrognathia), and neither of the other deformities had a prevalence of more than 10% (Papers I, II and III). This agrees quite well with the calculations of Proffit and White (1991), who estimated Class II malocclusions to be the most prevalent deformity in the US population. This prevalence of Class II deformities is also shown in paper V, in which we tried to get a more even distribution of various discrepancies, but this was hindered by either a lack of sufficiently high-quality pre- and postoperative radiographs for evaluations or the fact that part of the orthodontics was performed outside the hospital, which made cost comparisons difficult. Patients with bone grafts and major complications had to be excluded as well, since only the routine treatment process was being assessed.

In Paper II, the limitations of most previous studies dealing with the outcome of orthognathic surgery (small patient sample and/or short follow-up and/or retrospectiveness and/or high dropout rate and/or lack of accurate measurements and /or lack of controls) were avoided as far as possible by using a prospective study design, by calibrating the two examiners before the study, by having a study population of 60 with a mean follow-up of 4 years, by using well-known Helkimo's index as an essential part of the measurement tool and, importantly, by having a non-patient control population with basically similar malocclusions. The reason for only two examinations of the control

patients was the fact that the patients were recruited from the hospital waiting lists for treatment. Subjects who, at recall, refused to have orthognathic surgery, became control candidates. If they allowed a second clinical examination (in addition to the initial examination), they served as control subjects. This practice also caused variation in the follow-up times. A third examination would have caused a longer follow-up, which was not considered necessary.

Many of the previous studies on the psychosocial profiles of orthognathic surgery patients have been retrospective and/or based on patients' postsurgical recollections of their preoperative expectations. The value of many such studies is also reduced by substantial dropping out of patients during follow-up. (Auerbach *et al.* 1984, Flanary *et al.* 1985, Nagamine *et al.* 1986, Athanasiou *et al.* 1989a, Frost & Peterson 1991, Finlay *et al.* 1995, Cunningham *et al.* 1996a, b). Although, in some studies, patients have been assessed both before and after surgery (Auerbach *et al.* 1984, Garvill *et al.* 1992), standardized questionnaires have been used in few (Kiyak *et al.* 1982, 1986, Lovius *et al.* 1990, Ostler & Kiyak 1991, Finlay *et al.* 1995). In the present prospective Paper I, only 4% of the patients were lost to 1-year follow-up, and standardized questionnaires were used, which facilitated comparisons.

The dropout rate was also small in Paper II (6.7%) and nil in Paper IV, while the Papers III and V were retrospective.

In Paper IV, an effort was made to keep all the other clinical and intraoperative variables except the soft tissue retraction technique similar on both the study and the control sides by, for example, excluding every case with intraoperatively suspected macroscopic nerve trauma. The other known risk factors (the amount of distal segment advancement or the patient's age, Ylikontiola 2002) were not present, either, due to the fact that each patient acted as his/hers own control.

## **6.2 Expectations and perceptions regarding orthognathic surgery**

The assessed issues of this study, adapted from Ostler and Kiyak (1991), have three aspects: functional problems, social interaction problems, and self-concept problems. The patients in this study were found to report preoperatively more functional problems (mastication, occlusion and TMJ problems) than problems with self-concept (facial, tooth or general appearance, feelings about self) or social interaction (performance at work, appearance in public). In contrast, Ostler and Kiyak (1991) found self-concept problems to be rated as equally serious as functional problems.

Paper III showed similar motive tendencies as Paper I: the vast majority of patients had functional problems (stiffness in the jaws, difficulties in chewing, joint sounds, damage to the teeth or gingiva/mucosa, difficulties in opening the mouth, preprosthetic problems) and pain (headache, pain in the jaw or neck and shoulders, fibromyalgia, TMJ pain) as either the main or an additional reason for seeking treatment. Among the specific motives for seeking treatment, the greatest difference between our patients in Paper I and the patients in many other studies was in the frequency of references to facial appearance. A recent study from Finland (Nurminen *et al.* 1999) reported figures almost identical to

ours. Up to 89% of patients have been reported by other authors to have esthetic motives for seeking treatment (Olson & Laskin 1980, Heldt *et al.* 1982, Flanary *et al.* 1985, Ostler & Kiyak 1991, LeBell *et al.* 1993). Phillips *et al.* (1997) found more patients to have primarily appearance/self-image-related motives than functional motives for seeking treatment. However, in the study of Frost and Peterson (1991), the number was as low as 4%. Even when only studies involving Scandinavian patients are considered, variation in the reported motives for treatment is evident. In two Swedish studies, esthetic motives for seeking treatment were found to be only slightly less important than or equally important as functional motives (Wictorin *et al.* 1969, Garvill *et al.* 1992, Ek *et al.* 1997), but in a Danish study (Athanasίου *et al.* 1989a), functional reasons were cited more often than esthetic reasons. Maybe, therefore, not all differences in motives should be attributed to merely sociocultural differences relating to the importance of facial appearance. Part of these differences may be due to the differing information given by professionals and the patients' responses to it; the type of dentofacial deformity could also play an important role: the majority of patients in this study (Paper I, II, III) had Class II deformity (or mandibular hypoplasia), which mostly does not seem to be experienced as esthetically equally unfavourable as Class III (or mandibular prognathia) or long-face deformities (Proffit *et al.* 1990, Zhou *et al.* 2001, Gerzanik *et al.* 2002).

Functional and pain-related problems correlated positively with the patient's age, and the patients with cosmetic reasons were younger (Paper III). A positive correlation between function and age was also seen in Paper II: A<sub>i</sub> showed higher scores in the older group of patients (> 30 years) before treatment, and this group also experienced greater benefits after treatments. It thus seems that although no major deterioration in TMD occurs along with higher age (Magnusson *et al.* 2000), the existing signs and symptoms may become more disturbing with age.

Interestingly, more patients reported postoperative improvement of facial appearance than reported such improvement as their motive for seeking treatment. Frost and Peterson (1991) also reported satisfaction with the post-treatment esthetic changes of their patients, although they listed functional problems as their motivation for seeking treatment. This may be associated with the severity of the deformity or indicate that even the patients with functional motives may have hidden esthetic motives for treatment. They may believe themselves to be more acceptable for treatment if they report motives other than esthetic to the professionals.

One year after surgery, a significant reduction in the problems and symptoms, except with regard to general health and performance at work, was observed. Aspects related to function had improved most, but even aspects not considered very problematic before surgery had improved somewhat. Thus, it seems that the most important aims in seeking treatment, such as reduction in TMJ problems, were most often perceived as having been achieved.

On the whole, the patients in this study seemed to have had realistic expectations, and a high degree of correlation was found between the aims and the outcome. This high degree of correlation doubtless also resulted in the high degree of satisfaction with treatment. The high degree of satisfaction, mostly between near 80% to 100% of patients, which has also been reported in other studies (Nagamine *et al.* 1986, Cunningham *et al.* 1996a,b, Finlay *et al.* 1995, Garvill *et al.* 1992, Nurminen *et al.* 1999), has led to suggestions that it could be partly explained by dissonance: after the long treatment

process with major surgery, patients feel a need to justify what they have gone through by expressing satisfaction with the result (Kiyak & Bell 1991). The duration of postoperative orthodontics has been suggested to influence satisfaction (Kiyak *et al.* 1982), but no such effect was seen in the present study. Instead, the occurrence of paresthesia in the jaw did reduce satisfaction with the outcome.

The 'satisfaction with life' questionnaire showed our patients to be uniformly satisfied with all aspects of their lives. This finding strengthens the impression that those who seek orthognathic surgery are psychologically stable.

The benefits and effectiveness of treatments in various illnesses can also be described as changes in the quality of life. Sickness Impact Profile (SIP) (Bergner *et al.* 1981) is a widely used questionnaire-based instrument designed to measure the physical, psychosocial and overall dimensions in a broad range of health-related functional disabilities. It is a generic measure and might not be sensitive to change in specific aspects of oral function or health, but enables us to compare diseases or conditions with each other, as shown in Fig. 7. The figure has been adapted from a study by Hatch *et al.* (1998), in which they also used another, disease-specific instrument designed for use with orthognathic surgery patients: the Oral Health Status Questionnaire (OHSQ). They studied a Class II malocclusion population with these two instruments before and after BSSO, and as it can be seen in Fig. 7, the health-related disability associated with Class II malocclusion was modest compared to many other medical conditions. Nonetheless, these patients exhibited progressive and significant improvement in health-related quality of life across a wide variety of functional domains. In this respect, this improvement can be interpreted to reflect a high level of success and cost-effectiveness.

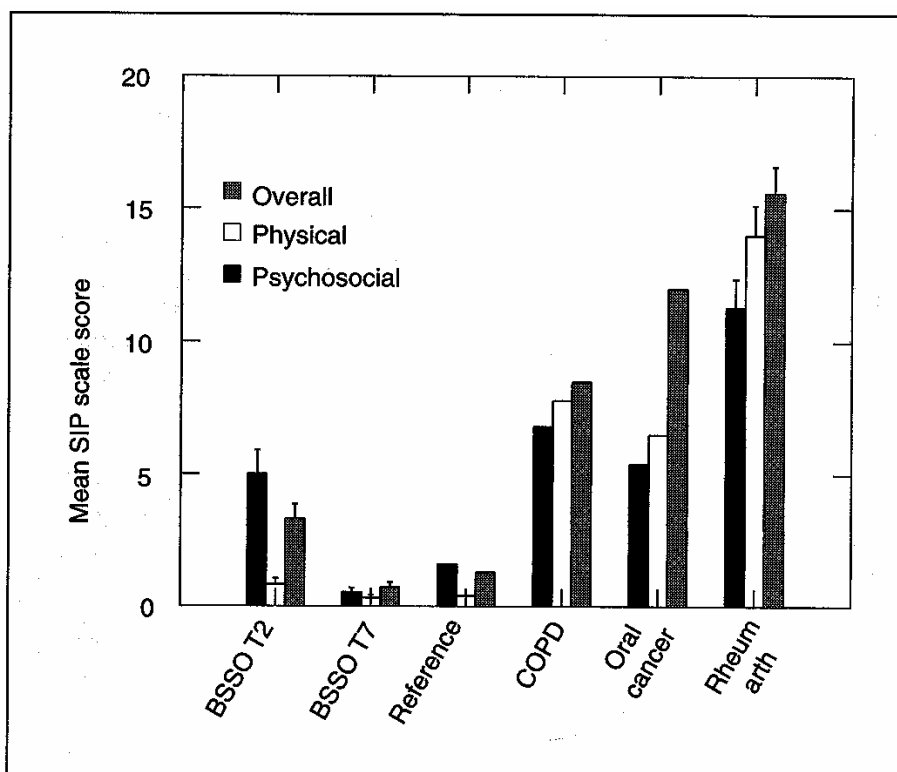


Fig. 7. Means and standard errors (where available) of Sickness Impact Profile (SIP) for patients undergoing orthognathic surgery and those suffering from other medical conditions."BSSO T2" and "BSSO T7" refer to presurgical and 24-month postsurgical data, respectively, from the study of Hatch et al. (1998). "Reference" refers to data from a stratified, randomly selected sample of 145 individuals from Stockholm County, Sweden. "COPD" refers to data collected from 68 patients with chronic obstructive pulmonary disease."Oral cancer" refers to data from 15 oropharyngeal cancer patients before surgery."Rheum arth" refers data from 79 patients with rheumatoid arthritis. (Hatch et al. 1998).

### 6.3 Effects of orthognathic surgery on TMD and masticatory function

It seems that the present patients seeking orthognathic surgery had significantly more TMD than the non-patient population. This is probably at least partly due to the referral pattern: most of the patients are referred to consultations by professionals, who presumably emphasize functional matters in the treatment. Another explanation could be the mean age of the patients, which was over 30 years in all Papers of the present study, and as mentioned in the former chapter, functional and pain-related problems seem to

concern especially older patients (Kuttilla 1998). The criteria for included signs and symptoms of TMD may also vary between studies.

The 73% prevalence of pretreatment signs and symptoms of TMD was among the highest rates reported in the literature in orthognathic surgery populations, and a considerably high prevalence of 46% was also reported in the retrospective Paper III. TMD in earlier reports has mostly varied between 14% and 54% (Laskin *et al.* 1986, Kerstens *et al.* 1989, Ingervall *et al.* 1979, Karabouta & Martis 1985, White & Dolwick 1992, Eriksson *et al.* 1990, Magnusson *et al.* 1990), but figures as high as 80% and 97% have also been presented (Schneider & Witt 1991, Link & Nickerson 1992). Our figure, 73%, lies at the upper limit of variation of signs and symptoms of TMD (40–75%) in non-patient adult populations presented in the literature (Kuttilla 1998), although a recent Finnish epidemiologic non-patient study reported as low figures as 12% (male) and 18% (female) for facial pain and 21% and 28% for clicking of the TMJ (Rauhala *et al.* 2000). However, the prevalence of severe dysfunction has been reported to be much lower. In a study of Salonen *et al.* (1990), for example, the prevalence of severe TMD, measured as Helkimo's DiIII, was lower than 1%, whereas in our study, the prevalence of severe dysfunction (DiIII) was 8% in the study group and 15% in the control group, while the prevalences of moderate symptoms (DiII) were 73% and 65%, respectively (Paper II).

After orthognathic surgery, a significant reduction was observed in signs and symptoms of TMD. This change was already evident at the one-year control visit, and only slight improvement took place after that. The greatest change occurred in joint pain and muscle pain on palpation, while joint crepitation and joint clicking actually increased, as they also did in the study of Smith *et al.* (1992). The reduced joint pain, crepitus and especially tenderness to muscle palpation contributed to the statistically significant improvement in Helkimo's Ai and Di compared to the baseline and the control group. The common TMD sign, clicking, has been reported to improve in some other studies (Sostman *et al.* 1991, Feinerman & Piecuch 1995 rigid fixation group), but they mostly do not report the way in which clicking was diagnosed. In our study, clicking was diagnosed both by palpation and by auscultation. One of the benefits of correction of dentofacial deformity may also be that myofascial pain reduction and improved and balanced occlusion may lead to favourable changes in dietary habits, encouraging a fibre-rich diet (Raphael *et al.* 2002).

This study failed to show a statistical correlation with any specific type or severity of dentofacial deformity and TMD, thus corroborating other studies (Sostman *et al.* 1991, Smith *et al.* 1992, White & Dolwick 1992, Onizava *et al.* 1995, Rodrigues-Garcia *et al.* 1998). However, most of the patients in our Paper II had mandibular hypoplasia, as also in the studies of White and Dolwick (1992) (61%), Smith *et al.* (1992) (100%) and Rodrigues-Garcia *et al.* (1998) (100%), and the numbers of subjects in the other dentofacial deformity groups were quite small. Therefore, statistical comparisons are less feasible between the different types of deformity than between the rates of severity or magnitudes of a single type of deformity. However, some common features can be found in studies reporting effects of orthognathic surgery on TMD (Table 1): patients with mandibular hypoplasia, especially those with a normal/low mandibular plane angle, seem to have a higher prevalence of TMD than most other discrepancies; patients with mandibular hypoplasia seem to improve with treatment more than others; this improvement in TMD is most striking in muscular tenderness/pain and less striking, or

even controversial, in signs of internal derangement, such as joint noises (clicking, crepitus). In contrast to this, Westermarck *et al.* (2001) found patients with mandibular prognathia to do slightly better than those with retrognathia, but muscle tenderness was not assessed in that study, where joint noises constituted the greatest portion of TMD. On the other hand, the tendency of mandibular hypoplasia/class II patients to have more TMD than controls with normal occlusion and the tendency of Class II patients to benefit functionally from orthodontic treatment have been demonstrated by Henrikson *et al.* (1997, 2000) and Henrikson & Nilner (2000). Especially the patients with muscular signs of TMD seemed to benefit from orthodontics. A preoperative study by Fernandez Sanroman *et al.* (1997) found internal derangements to be significantly more common in Class II subjects (54%) compared to subjects with Class I and III (10%).

Although “association never proves causality”, an assumption can be made that, in dentofacial deformities severe enough to warrant surgical correction, the biomechanical changes occurring in the masticatory muscles contribute to less and/or physiologically more favourable muscle activity patterns, which, in turn, may decrease the tenderness and pain and even headache. This would, as shown in the earlier chapter, hold true at least in most of the Class II patients, especially in those with a low or normal mandibular plane angle. Kerstens *et al.* (1989) found patients with muscular symptoms of TMD to have a better chance of improvement after orthognathic surgery than patients with TMJ disc dysfunction. Throckmorton *et al.* (1984) have shown with EMG studies that orthognathic surgery produces changes in the mechanical advantage of jaw muscles and also alters muscle function. In their later isometric bite force and EMG study (Throckmorton *et al.* 1995), the authors concluded that mandibular advancement surgery produces some significant functional benefits. Proffit *et al.* (1989) also found significant changes in the mechanical advantages of the masticatory muscles and suggested even physiological changes caused by altered sensory and proprioceptive inputs. Recently, Harper *et al.* (1997) showed with EMG investigations muscle recruitment changes to occur after mandibular advancement surgery in lateral pterygoid and temporalis muscles. They suggested these changes to be closely related to the proprioceptive feedback mechanism resulting from improved dental occlusion. Especially fine positioning movements of the mandible were altered, which is of major significance with regard to nonmasticatory activities of oral communication, such as speech, singing and playing musical instruments.

The difficulty in establishing a causal relationship is probably related to the adaptive relationship between form and function, and individuals with the same dentofacial skeletal deformity may respond to these factors in unique ways (Proffit *et al.* 1989). There are, on the other hand, also many studies reporting a correlation between TMD and certain malocclusion types. TMD has been found to correlate with overjet (Solberg *et al.* 1986, Riolo *et al.* 1987, Henrikson *et al.* 1997, Sonnesen *et al.* 1998), overbite (Lieberman *et al.* 1985, Solberg *et al.* 1986, Motegi *et al.* 1992) and open bite (Riolo *et al.* 1987, Henrikson *et al.* 1997, Sonnesen *et al.* 1998). These are, however, reports of orthodontic populations. Orthognathic surgery populations are more or less selected samples, and in our study, for example, 81% of the patients belonged to the clinical dysfunction classes DiII or DiIII (Helkimo 1974), while in the study of Rodrigues *et al.* (1998), the average dysfunction scores were extremely low (only 11 patients out of 124 had CMI scores higher than 0.30 on a scale of 0–1.0). It seems logical that, with these

small variations in TMD, it is difficult to establish a correlation with morphology. A more reliable way would be an epidemiological study among an adult population.

The incidence of new TMD in previously asymptomatic patients was 6.7%, which percentage is among the lowest reported (Table 1). Since three subjects (15%) in our control group also developed TMD, this can be assumed to be within the limits of spontaneous variation. No progressive condylar resorption was seen in Paper II.

## 6.4 Complications

Although the literature shows that orthognathic surgery may involve some potentially dangerous risks, complications in orthognathic surgery are rare and severe complications quite infrequent. The present study showed that the most common complication is neurosensory deficit of IAN. Approximately one third of the patients with mandibular sagittal ramus osteotomy, may experience mild disturbance of IAN function described as numbness, usually in a very limited area of the lip or chin, “stiffness or different sensation” or “thickness” of the lip or chin or a sensation of mild “electric current” or cold (papers III and IV). More severe sensory disturbances were reported by about 3% of the patients, and they included numbness in a larger area of the lip or chin disturbing everyday life or a burning sensation. After the publication of Paper III, we also had three cases of very severe IAN neuropathy, presenting as painful, mostly burning sensations (unpublished data). One of these resolved gradually 3 to 5 months after BSSO, one patient still has much of the burning sensation left, and the third is still suffering from severe neuropathy and intends to file a retirement application. No nerve was visibly injured in these operations. The common feature of all of these patients was the age at operation: 49, 55 and 57 years (mean age 54 years). Advanced age has been shown to be an important risk factor both in our studies (Papers III and IV) and in others (Westermarck 1999, Ylikontiola 2002). Other risk factors are the degree of manipulation of IAN, the magnitude of intraoperative mandibular movement (Ylikontiola 2002) and the surgeon’s skills (Westermarck 1999).

Clinical experience has often shown that, despite perfectly successful splitting of the ramus and without any visible damage to the IAN, the immediate postoperative sensation in the lower lip and chin may be severely disturbed (Westermarck 1999). This study showed that, with an appropriate and gentle instrumentation technique in BSSO soft tissue dissection, some of neurosensory deficits may be avoided. A vitality scanner test and two-point discrimination seem to be feasible bedside neurosensory testing methods in clinical practice, perhaps supplemented with the pin pressure nociception test, as recommended by Ylikontiola (2002). Recently, Teerijoki-Oksa *et al.* (2003) have found touch detection test to be most sensitive and clinically useful method. Neurosensory deficits may also contribute to dissatisfaction with the overall treatment outcome (Paper I) and even claims (Paper III).

The percentages of reoperations and severe relapse were 3% each. The former can be regarded as surgical failures due to difficulties to seat the condyles properly or mobilize the osteotomized segments sufficiently, loosening of the rigid fixation material, etc. The

latter may be caused by several factors, which have been described in details elsewhere. Both of these complications increase patient discomfort and cause considerable extra costs.

The mean blood loss did not increase despite the increasingly complicated surgical operations towards the late 1980's and until 1996. This is in line with the development of the anesthetic and surgical techniques and the reduction of the mean operation time from 200 min in 1988 to approximately 120 min in 1995–1996 as well as the shortening of the mean inpatient period (5.5 days in 1984 and 3.0 in 1996).

The risk for severe bleeding problems seemed to be very low and therefore does not warrant wider routine screenings for blood coagulation. Patients with syndromes or abnormal anatomy may be a risk group, as shown by our most severe intraoperative bleeding episode in a patient with an abnormally short neck and low mandibular ramus. Routine blood reservations are no longer done in our unit for orthognathic surgery.

Condylar resorption after orthognathic surgery is a controversial issue. The overall incidence of this condition was 11%, but an incidence of 7% was already seen before any treatments, while 5% became manifested during and after the treatments (Paper III). In the prospective follow-up part of the present study, no condylar resorption was observed at all (paper II). Most patients (75%) with progressing condylar resorption were operated with BSSO advancement, in which, inadvertant, too anterior rotation of the proximal fragment may cause compression to the condylar head resulting in remodelling or resorption. On the other hand, in 63% of the condylar resorption patients, the mandibular plane angle was greater than 32°, which suggests a tendency to skeletal open bite. This has been earlier shown to be a risk factor for condylar resorption (Bouwman *et al.* 1994, De Clercq *et al.* 1994, Hoppenreijis *et al.* 1998) and should be carefully evaluated when planning orthognathic surgery for these patients, especially if the other contributing risk factors mentioned earlier in chapter 2.5.2 also exist. It seems that esthetic or/and functional indications must be heavy to outweigh the risks of condylar resorption and relapse in many of the open-bite deformities. Due to the costly bimaxillary surgery often needed in these cases, the chances for poor cost-effectiveness in treatment are high.

Root resorption was asymptomatic and did not influence the treatment, but was detected in radiographic examinations. It was probably caused by orthodontics. Although root resorption has been proposed to be present more often in orthodontic camouflage (Tucker 1995), it also seems to be a risk in orthognathic surgery, and patients should be warned of this.

In response to Cunningham *et al.* (1995), who suggested that litigation may be an indirect expression of dissatisfaction with treatment, it can be concluded that, on the basis of the PIC complaint statistics, it generally seems that the present patients had been adequately informed of the various aspects of orthognathic surgery and their expectations of treatment were fulfilled. Only 63 official complaints concerning orthognathic surgery were filed in Finland during the 1990's, while the total number of claims covering all fields of medicine in the same period was 59,689. The real dissatisfaction rate is probably higher, and most of the patients who experience complications apparently chose not to file official complaints. Rittersma (1989) concludes that a written information manual covering all fields of orthognathic surgery is important, but verbal communication between the professionals and the patient remains the key to patient preparation. No postoperative depression was seen in this study.

The differences in operation times between the figures mentioned in paper III and V of the present study can be explained with the attendance of inexperienced surgical resident to the most of the operations until year 1996. Most of the patients in the later part of the present study (paper V) were operated after 1996, mainly by one specialist surgeon.

## 6.5 Costs

Contemporary orthognathic surgery is not merely a surgical procedure, but also includes orthodontics as an essential part of the process. This study aimed to evaluate the costs and their distributions in the entire treatment process of orthognathic surgery (paper V). It also tried to identify various, mainly patient-dependent cost factors, which would help to predict the costs in advance while planning the treatment. Approximately 39% of the costs are due to the orthodontics with an average of 26 visits, and 61% are due to surgery, 28% of which were caused by the surgical operation itself. The average total cost was 6206 USD, but if the malocclusion could be operated with the BSSO technique, the costs were only 5839 USD, whereas the deformities that required a bimaxillary operation cost 7342 USD ( $p < 0.05$ ). The data also showed that patients with open-bite deformities had the highest expenses, which is obvious in view of the fact that these deformities usually require bimaxillary operations. No other specific cost factors among the cephalometric or clinical characteristics could be found to correlate with open bite, apart from the fact that, in some cases, it had been difficult to orthodontically close the remaining open bite postoperatively. This may reflect failures in preoperative orthodontics or surgical repositioning of the osteotomized fragments. There was, on the other hand, a positive correlation between deep bite and the outpatient costs. This malocclusion turned out to cause problems in orthodontics due to loosening of parts of the fixed appliances.

Space closure after tooth extractions for orthodontic reasons enhanced expenses, probably due to the more time and efforts needed to align the arches. This speaks for non-extraction treatment whenever possible, and the esthetic results may also be better when nasolabial support can be preserved with all existing maxillary teeth.

## 6.6 General comments and clinical implications

Despite the abundant research on orthognathic surgery, there still seem to exist many open questions. Etiology, epidemiology, TMJ function, indications for and outcome of orthognathic surgery and economic aspects involve uncertainty and controversy or have not been much studied. Cost-benefits and cost-effectiveness have hardly been discussed at all. When we are dealing with elective surgery, the benefits should clearly outweigh the possible adverse effects. The competition for economic resources obliges the health care service producers to justify the treatment practices with more accurate results.

Human biophysiological phenomena are basically the same throughout the world, but psychosocial backgrounds may differ considerably between cultures. Dentofacial

deformities, when serious enough to warrant surgical-orthodontic therapy, involve both psychosocial and biological considerations. Little is known about these from the Finnish point of view, although orthognathic surgery services are available routinely in almost all parts of Finland. The aim of this study was to introduce a comprehensive view to clarify some of the open questions.

The majority of patients in this study reported pain-related or functional problems as the reasons for seeking orthognathic surgery. This impression was confirmed by the clinical findings of a high prevalence of TMD. Nevertheless, esthetic concerns cannot be ignored, as facial disfigurement due to dentofacial deformities may represent a psychological handicap (Belfer *et al.* 1982, Tobiasen *et al.* 1987). The high level of patient satisfaction with the treatment without any evident psychological adverse effects and with a low official complaint rate shows good cost-effectiveness in the psychosocial respect.

The effects of orthognathic surgery on TMD turned out to be favourable in this study, although some of the signs and symptoms failed to disappear. It seems, however, that the positive treatment outcome mainly occurred in patients with skeletal Class II, non-open-bite deformities (or mandibular hypoplasia/retrognathia), who have TMD of mainly muscular pain origin or muscle contraction headache. To increase the degree of certainty in the diagnostic phase of this category, temporary occlusal splint therapy can be recommended (Tucker & Thomas 1986) as well as repeated measurements of TMD before treatment due to the fluctuation of the symptoms. Those with TMD of internal derangement type may or may not benefit from orthognathic surgery, similarly to other dentofacial deformities. The patients with skeletal Class II, non-open bite deformity can most often be treated with orthodontics and BSSO, which was found to be overall the cheapest treatment compared to the others. The complication rate is also extremely low, the only complication being neurosensory disturbance of IAN, which is pretty much avoidable with careful patient selection and a good, gentle surgical technique. When these prerequisites are taken into account, orthognathic surgery can be regarded as cost-effective and probably also increases the quality of life as shown by Hatch *et al.* (1998), Fig.7.

However, dentofacial deformities with skeletal open bite constitute a more controversial category. Although some improvement in TMD would be gained with orthognathic surgery, the risk for relapse is considerably high, varying within 3–35% of cases, as reported in numerous studies (Haymond *et al.* 1991, Denison *et al.* 1989, Fischer *et al.* 2000, Hoppenreijns *et al.* 1996, Lopez-Gavito *et al.* 1985). Recently, Aghabeigi *et al.* (2001) examined TMD in an open-bite deformity group and found preoperatively 32% to suffer from TMJ pain, 40% from dysfunction and 7% from limited opening. The overall prevalence of TMD was not significantly different after orthognathic surgery. Since the correction of these deformities often also requires bimaxillary surgery, the expenses of their treatment may be high. Kerstens *et al.* (1989) found asymptomatic patients with a high mandibular plane angle (skeletal open bite) operated on by means of bimaxillary surgery to show a higher incidence of postoperative TMD compared to the other dentofacial deformities. An explanation for this has suggested to lie in the potential joint pathology due to a different morphology of the TMJs in patients with mandibular hypoplasia with a high mandibular plane angle (O’Ryan & Epker 1984). Open-bite deformities are also prone to condylar resorption,

especially if the subject is a young female with posteriorly inclined condyles (Hoppenreijns *et al.* 1998). Therefore, cost-effectiveness in these deformities may be low.

Although, at an individual level, it may be difficult to predict the treatment outcome exactly, on the basis of the earlier literature and the present study, some clinical recommendations for orthognathic surgery can be suggested:

- if mandibular surgery is needed, it is preferable to have orthognathic surgery performed before the age of 30, in order to minimize risk for neurosensory IAN disturbances. If the patient is over 50 years of age, only heavy indications for sagittal ramus osteotomy outweigh the potential risk for IAN damage.
- patients with skeletal Class II non-open bite deformity, who have TMD of mainly muscular origin with or without headache, seem to benefit most from orthognathic surgery. Before definitive decisions, measurement tools, such as Helkimo's Dysfunction Index (1974) or TMD Treatment Need Classification (Kuttila *et al.* 1998) for pretreatment assessments, are recommended due to the fluctuation of TMD. Temporary occlusal splint therapy could be tried as a pretreatment test.
- patients with handicapping, unesthetic dentofacial discrepancy should evidently be offered treatment even without any pre-existing functional or pain-related problems. Measurement tools, such as the Index of Treatment Need (IOTN) (Brook & Shaw 1989), can be used in evaluations of these subjects.
- patients with skeletal open-bite deformity must be assessed with special care before the decision to perform orthognathic surgery due to the lower cost-effectiveness of the treatment. If treatment is highly indicated, consider LeFort I osteotomy instead of bimaxillary procedures due to the lesser risk for condylar resorption (Hoppenreijns *et al.* 1998) and the lower costs.
- because no direct association between the magnitude of malocclusion and TMD has been proven, prophylactic treatment of asymptomatic dentofacial deformities does not seem to be indicated.

## 7 Conclusions

1. The majority of patients in this study reported pain-related or functional problems as the reasons for seeking orthognathic surgery. This impression was confirmed by the clinical findings of a high prevalence of TMD. These issues were also best resolved by orthognathic surgery. The finding that functional and pain-related issues were of greater significance to patients than esthetic concerns differs from the findings of most previous studies. The high level of patient satisfaction with the treatment without any evident psychological adverse effects and with a low official complaint rate shows good cost-effectiveness in the psychosocial respect.
2. Patients with skeletal Class II non-open-bite deformities, who have TMD of mainly muscular origin with or without recurrent headache, seem to benefit most from orthognathic surgery. Those with TMD of more internal derangement type may or may not benefit from orthognathic surgery, similarly to other dentofacial deformities. Prophylactic treatment of asymptomatic dentofacial deformities cannot be recommended on the basis of the present study.
3. Complications in orthognathic surgery are rare, and severe complications are even less frequent. The most common complication is neurosensory deficit of the inferior alveolar nerve. Minimal soft tissue retraction of the ascending mandibular ramus in the initial phase of sagittal ramus osteotomy apparently decreases the risk of damage to this nerve. The occurrence of paresthesia in the jaw decreased satisfaction with the treatment outcome.
4. The treatment of patients with skeletal Class II, non-open-bite malocclusion was found to be the cheapest mode of treatment, if treatment included only BSSO in addition to orthodontics. Treatment of these patients with TMD symptomatology of muscular origin can be regarded as cost-effective and probably also improves the quality of life. Patients with skeletal open-bite deformities must be assessed with special care before a decision to do orthognathic surgery due to the lower cost-effectiveness of the treatment.

## References

- Aghabeigi B, Hiranaka D, Keith DA, Kelly JP & Crean StJ (2001) Effect of orthognathic surgery on the temporomandibular joints in patients with anterior open bite. *Int J Adult Orthod Orthognath Surg* 16: 153–160.
- Arndt EM, Travis F, Lefebvre AN, Niec A & Munro IR (1986) Beauty and the eye of the beholder: social consequences and personal adjustments for facial patterns. *Brit J Plast Surg* 39: 81–84.
- Arnett GW & Tamborello JA (1990) Progressive Class II development – female idiopathic condylar resorption. In: West RA (1990) ed. *Oral and maxillofacial clinics of North America*. Philadelphia: WB Saunders: 699–716.
- Arnett GW, Milam SB & Gottesman L (1996a) Progressive mandibular retrusion- idiopathic condylar resorption. Part I. *Am J Orthod Dentofac Orthop* 110: 8–15.
- Arnett GW, Milam SB & Gottesman L (1996b) Progressive mandibular retrusion- idiopathic condylar resorption. Part II. *Am J Orthod Dentofac Orthop* 110: 117–127.
- Athanasiou AE, Elefteriadis JN & Dre E (1996) Short-term functional alterations in the stomatognathic system after orthodontic-surgical management of skeletal vertical excess problems. *Int J Adult Orthod Orthognath Surg* 11: 339–346.
- Athanasiou AE, Melsen B & Eriksen J (1989a) Concerns, motivation, and experience of orthognathic surgery patients: a retrospective study of 152 patients. *Int J Adult Orthod Orthognath Surg* 4: 47–55.
- Athanasiou AE, Melsen B, Mavreas D & Kimmel FB (1989b) Stomatognathic functions of patients who seek orthognathic surgery to correct dentofacial anomalies. *Int J Adult Orthod Orthognath Surg* 4: 239–254.
- Auerbach SM, Meredith J, Alexander JM, Mercuri LG & Brophy C (1984) Psychological factors in adjustment to orthognathic surgery. *J Oral Maxillofac Surg* 42: 435–440.
- Baddour HM, Watson J, Erwin BJ, Clark MJ, Holt GR, Steed DL & Tilson HB (1981) Tympanometric changes after total maxillary osteotomy. *J Oral Surg* 39: 336–339.
- Baker DL, Stoelinga PJW, Blijdorp PA & Brouns JJA (1992) Long-term stability after inferior maxillary repositioning by miniplate fixation. *Int J Oral Maxillofac Surg* 21: 320–326.
- Belfer ML, Harrison AM, Pillemer FC & Murray JE (1982) Appearance and the influence of reconstructive surgery on body image. *Clin Plast Surg* 9: 307–315.
- Bell WH, Fonseca RJ, Kennedy JW & Levy BJ (1975) Bone healing and revascularization after total maxillary osteotomy. *J Oral Surg* 33: 253–260. In: Proffit WR & White RP Jr (1991) *Surgical-Orthodontic Treatment*. Mosby, St. Louis, p. 248–263.
- Bell WH & Schendel SA (1977) Biologic basis for modification of the sagittal ramus split osteotomy. *Journal of Oral Surgery* 35: 362–369.
- Bell WH, You ZH, Finn RA & Fields RT (1995) Wound healing after multisegmental LeFort I osteotomy and transection of the descending palatine vessels. *J Oral Maxillofac Surg* 53: 1425–1433.

- Berger P (1897) Du traitement chirurgical du prognathisme. Lyon; Med These.
- Bergner M, Bobitt RA, Carter WB & Gilson BS (1981) The Sickness Impact Profile: Development and final revision of health status measure. In: Hatch JP, Rugh JD, Clark GM, Keeling SD, Tiner BD & Bays RA (1998) Health-related quality of life following orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 13: 67–77.
- Bouwman JPB, Kerstens HCJ & Tuinzing DB (1994) Condylar resorption in orthognathic surgery. The role of intermaxillary fixation. *Oral Surg Oral Med Oral Pathol* 78: 138–141.
- Brook PH & Shadow WC (1989) The development of an index for orthodontic treatment priority. *Eur J Orthod* 11: 309–332.
- Buckley MJ, Tulloch JFC, White RP Jr & Tucker MR (1989) Complications of orthognathic surgery: A comparison between wire fixation and rigid internal fixation. *Int J Adult Orthod Orthognath Surg* 4: 69–74.
- Burgersdijk R, Truin GJ, Frankenmolen F, Kalsbeek H, van't Hof M & Mulder J (1991) Malocclusion and orthodontic treatment need of 15–74-year old Dutch adults. *Community Dent Oral Epidemiol* 19: 64–67.
- Bush FM (1985) Malocclusion, masticatory muscle, and temporomandibular joint tenderness. *J Dent Res* 64: 129–133.
- Caldwell JB & Letterman GS (1954) Vertical osteotomy in the mandibular rami for correction of mandibular prognathism. *J Oral Surg* 12: 185–193.
- Christiansen RL & Soudah HP (1993) Disseminated intravascular coagulation following orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 8: 217–224.
- Converse JM & Horowitz SL (1969) The surgical-orthodontic approach to the treatment of dentofacial deformities. *Am J Orthod* 55: 217–243.
- Costen JB (1934) A syndrome of ear and sinus symptoms dependent upon disturbed function of the temporomandibular joint. *Ann Otol* 43: 1–15.
- Cunningham SJ, Hunt NP & Feinmann C (1995) Psychological aspects of orthognathic surgery: A review of literature. *Int J Adult Orthod Orthognath Surg* 10: 159–172.
- Cunningham SJ, Hunt NP & Feinmann C (1996a) Perceptions of outcome following orthognathic surgery. *Br J Oral Maxillofac Surg* 34: 210–213.
- Cunningham SJ, Crean SJ, Hunt NP & Harris M (1996b) Preparation, perceptions, and problems: A long-term follow-up study of orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 11: 41–47.
- Cutbirth M, Van Sickels JE & Thrash WJ (1998) Condylar resorption after bicortical screw fixation of mandibular advancement. *J Oral Maxillofac Surg* 56: 178–182.
- Dahlberg G, Petersson A, Westesson P-E & Eriksson L (1995) Disk displacement and temporomandibular joint symptoms in orthognathic surgery patients. *Oral Surg Oral Med Oral Pathol* 79: 273–277.
- Dal Pont G (1961) Retromolar osteotomy for correction of prognathism. *J Oral Surg Anesth Hosp D Serv* 19: 42–47.
- Dean JS, Throckmorton GS, Ellis E 3rd & Sinn DP (1992) A preliminary study of maximum voluntary bite force and jaw muscle efficiency in preorthognathic surgery patients. *J Oral Maxillofac Surg* 50: 1284–1288.
- De Clercq CA, Neyt LF, Mommaerts MY, Abeloos JV & De Mot BM (1994) Condylar resorption in orthognathic surgery: A retrospective study. *Int J Adult Orthod Orthognath Surg* 9: 233–240.
- De Clercq CA, Abeloos JV, Mommaerts MY & Neyt LF (1995) Temporomandibular joint symptoms in an orthognathic surgery population. *J Craniomaxillofac Surg* 23: 195–199.
- De Jongh M, Barnard D & Birnie D (1986) Sensory nerve morbidity following Le Fort I osteotomy. *J Maxillofac Surg* 14: 10–13.
- De Mol van Otterloo JJ, Tuinzing DB, Greebe RB & van der Kwast WAM (1991) Intra- and early postoperative complications of Le Fort I osteotomy: A retrospective study on 410 cases. *J Craniomaxillofac Surg* 19: 217–222.
- Denison TF, Kokich VG & Shapiro PA (1989) Stability of maxillary surgery in openbite versus nonopenbite malocclusions. *Angle Orthod* 59: 5–10.
- Dimitroulis G (1998) A simple classification of orthognathic surgery complications. *Int J Adult Orthod Orthognath Surg* 13: 79–87.

- Dolce C, Van Sickels JE, Bays RA & Rugh JD (2000) Skeletal stability after mandibular advancement with rigid versus wire fixation. *J Oral Maxillofac Surg* 58: 1219–1227.
- Dolce C, Hatch JP, Van Sickels JE & Rugh JD (2002) Rigid versus wire fixation for mandibular advancement: skeletal and dental changes after 5 years. *Am J Orthod Dentofac Orthop* 121: 610–619.
- Dolan P, White RP Jr & Tulloch JFC (1987) An analysis of hospital charges for orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 1: 9–14.
- Dolan P & White RP Jr (1996) Community hospital charges for orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 11: 253–255.
- Edgerton MT & Knorr MJ (1971) Motivational patterns of patients seeking cosmetic (aesthetic) surgery. *Plast Reconstr Surg* 48: 551–557.
- Edwards DB, Scheffer RB & Jackler I (1986) Postoperative pneumomediastinum and pneumothorax following orthognathic surgery. *J Oral Maxillofac Surg* 44: 137–141.
- Egermark-Eriksson I, Carlsson GE & Magnusson T (1987) A long-term epidemiological study of the relationship between occlusal factors and mandibular dysfunction in children and adolescents. *J Dent Res* 66: 67–71.
- Egermark I, Blomqvist JE, Cromvik U & Isaksson S (2000) Temporomandibular dysfunction in patients treated with orthodontics in combination with orthognathic surgery. *Eur J Orthod* 22: 537–544.
- Ehmer U & Broll P (1992) Mandibular border movements and masticatory patterns before and after orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 7: 153–159.
- Ek E, Persson J & Lundgren S (1997) Surgical correction of dentofacial anomalies: an evaluation of two patient groups with the aid of a questionnaire. *Swed Dent J* 21: 101–110.
- Ellis E & Hinton RJ (1991) Histologic examination of the temporomandibular joint after mandibular advancement with and without rigid fixation: An experimental investigation in adult *Macaca mulatta*. *J Oral Maxillofac Surg* 49: 1316–1327.
- Epker BN (1977) Modifications in the sagittal osteotomy of the mandible. *J Oral Surg* 35: 157–159.
- Epker BN (1984) Vascular considerations in orthognathic surgery. I. Mandibular osteotomies. *Oral Surg Oral Med Oral Pathol* 57: 467–472.
- Feinerman DM & Piecuch JF (1995) Long-term effects of orthognathic surgery on the temporomandibular joint: comparison of rigid and nonrigid fixation methods. *Int J Oral Maxillofac Surg* 24: 268–272.
- Fernandez Sanroman JF, Gomez Gonzalez JM & Alonso del Hoyo A (1997) Relationship between condylar position, dentofacial deformity and temporomandibular joint dysfunction: an MRI and CT prospective study. *J Craniomaxillofac Surg* 26: 36–42.
- Finlay PM, Atkinson JM & Moos KF (1995) Orthognathic surgery: Patient expectations; psychological profile and satisfaction with outcome. *Br J Oral Maxillofac Surg* 33: 9–14.
- Fischer K, von Konow L & Brattstrom V (2000) Open bite: stability after bimaxillary surgery – 2-year treatment outcomes in 58 patients. *Eur J Orthod* 22: 711–718.
- Flanary CM, Barnwell GM & Alexander JM (1985) Patient perceptions of orthognathic surgery. *Am J Orthod* 88: 137–145.
- Forsell H, Kirveskari P & Kangasniemi P (1985) Changes in headache after treatment of mandibular dysfunction. *Cephalalgia* 5: 229–236.
- Forsell H, Kirveskari P & Kangasniemi P (1986) Effect of occlusal adjustment on mandibular dysfunction. A double-blind study. *Acta Odontol Scand* 44: 63–69.
- Forsell H, Kirveskari P & Kangasniemi P (1987) Response to occlusal treatment in headache patients previously treated by mock occlusal adjustment. *Acta Odontol Scand* 45: 77–80.
- Forsell H, Kalso E, Koskela P, Vehmanen R, Puukka P & Alanen P (1999) Occlusal treatments in temporomandibular disorders: a qualitative systematic review of randomized controlled trials. *Pain* 83: 549–560.
- Frost V & Peterson G (1991) Psychological aspects of orthognathic surgery: How people respond to facial change. *Oral Surg Oral Med Oral Pathol* 71: 538–542.
- Gaggl A, Schultes G, Santler G, Karcher H & Simbrunner J (1999) Clinical and magnetic resonance findings in the temporomandibular joints of patients before and after orthognathic surgery. *Br J Oral Maxillofac Surg* 37: 41–45.

- Garvill J, Garvill H, Kahnberg K-E & Lundgren S (1992) Psychological factors in orthognathic surgery. *J Craniomaxillofac Surg* 20: 28–33.
- Gerzanik L, Jagsh R & Watzke IM (2002) Psychologic implications of orthognathic surgery in patients with skeletal Class II or Class III malocclusion. *Int J Adult Orthod Orthognath Surg* 17:75–81.
- Greene CS (2001) The etiology of temporomandibular disorders: Implications for treatment. *J Orofac Pain* 15: 93–105.
- Grime PD, Haskell R, Robertson I & Gullan R (1991) Transfacial access for neurosurgical procedures: an extended role for the maxillofacial surgeon . I. The upper cervical spine and clivus. *Int J Oral Maxillofac Surg* 20: 285–290.
- Guernsey LH & DeChamplain RW (1971) Sequelae and complications of the intraoral sagittal osteotomy in the mandibular rami. *Oral Surg Oral Med Oral Pathol* 32: 176–192.
- Harper RP, de Bruin H & Burcea I (1997) Muscle activity during mandibular movements in normal and mandibular retrognathic subjects. *J Oral Maxillofac Surg* 55: 225–233.
- Hatch JP, Rugh JD, Clark GM, Keeling SD, Tiner BD & Bays RA (1998) Health-related quality of life following orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 13: 67–77.
- Haymond CS, Stoelinga PJ, Blijdorp PA, Leenen RJ & Merkens NM (1991) Surgical orthodontic treatment of anterior skeletal open bite using small plate internal fixation. One to five year follow-up. *Int J Oral Maxillofac Surg* 20: 223–227.
- Heikinheimo K (1989) Need of orthodontic treatment and prevalence of craniomandibular dysfunction in Finnish children. (dissertation) Turun Yliopiston Hammaslääketieteen Laitoksen Kirjapaino.
- Heldt L, Haffke EA & Davis LF (1982) The psychological and social aspects of orthognathic treatment. *Am J Orthod* 82: 318–328.
- Helkimo M (1974) Studies on function and dysfunction of the masticatory system. II. Index for anamnestic and clinical dysfunction and occlusal state. *Swed Dent J* 67: 101–121.
- Helm S, Kreiborg S & Solow B (1985) Psychosocial implications of malocclusions: A 15 year follow-up study in 30-year-old Danes. *Am J Orthod* 87: 110.
- Henrikson T, Ekberg EC & Nilner M (1997) Symptoms and signs of temporomandibular disorders in girls with normal occlusion and Class II malocclusion. *Acta Odontol Scand* 55: 229–235.
- Henrikson T, Nilner M & Kurol J (2000) Signs of temporomandibular disorders in girls receiving orthodontic treatment. A prospective and longitudinal comparison with untreated Class II malocclusions and normal occlusion subjects. *Eur J Orthod* 22: 271–281.
- Henrikson T & Nilner M (2000) Temporomandibular disorders and the need for stomatognathic treatment in orthodontically treated and untreated girls. *Eur J Orthod* 22: 283–292.
- Hoppenreijts TJM, van der Linden FPGM, Freihofer HPM, van't Hof MA, Tuinzing DB, Voorsmit RACA & Stoelinga PJW (1996) Occlusal and functional conditions after surgical correction of open bite deformities. *Int J Adult Orthod Orthognath Surg* 11: 29–39.
- Hoppenreijts TJM, Freihofer HPM, Stoelinga PJW, Tuinzing DB & van't Hof MA (1998) Condylar remodelling and resorption after LeFort I and bimaxillary osteotomies in patients with anterior open bite. A clinical and radiological study. *Int J Oral Maxillofac Surg* 27: 81–91.
- Hullihen SB (1849) Case of elongation of the underjaw and distortion of the face and neck, caused by a burn, successfully treated. *Am J Orthod* 13: 67. In: Steinhauser EW (1996) Historical development of orthognathic surgery. *J Craniomaxillofac Surg* 24: 195–204.
- Hunsuck EE (1968) A modified intraoral sagittal splitting technique for correction of mandibular prognathism. *J Oral Maxillofac Surg* 26: 250–253.
- Hwang S-J, Haers PE & Sailer HF (2000) The role of posteriorly inclined condylar neck in condylar resorption after orthognathic surgery. *J Craniomaxillofac Surg* 28: 85–90.
- Ingervall B & Thilander B (1974) Relation between facial morphology and activity of the masticatory muscles. *J Oral Rehabil* 1: 131–147.
- Ingervall B, Ridell A & Thilander B (1979) Changes in activity of the temporal, masseter and lip muscles after surgical correction of mandibular prognathism. *Int J Oral Surg* 8: 290–300.
- Jacks SC, Zuniga JR, Turvey TA & Schalit C (1998) A retrospective analysis of lingual nerve sensory changes after mandibular bilateral sagittal split osteotomy. *J Oral Maxillofac Surg* 56: 700–704

- Jacobson A (1984) Psychological aspects of dentofacial aesthetics and orthognathic surgery. *Angle Orthod* 54: 18–35.
- Jones DL & Wolford LM (1990) Intraoperative recording of trigeminal evoked potentials during orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 5: 167–174.
- Jones JK & Van Sickels JE (1991) Facial nerve injuries associated with orthognathic surgery: A review of incidence and management. *J Oral Maxillofac Surg* 49: 740–744.
- Jääskeläinen SK, Peltola JK, Forssell K & Vähätalo K (1995) Evaluating function of the inferior alveolar nerve with repeated nerve conduction tests during mandibular sagittal split osteotomy. *J Oral Maxillofac Surg* 53: 269–279.
- Kahnberg KE & Enström H (1987) Recovery of maxillary sinus and tooth sensibility after LeFort I osteotomy. *Br J Oral Maxillofac Surg* 25: 68–73.
- Karabouta I & Martis C (1985) The TMJ dysfunction syndrome before and after sagittal split osteotomy of the rami. *J Maxillofac Surg* 13: 185–188.
- Karas ND, Boyd SB & Sinn DP (1990) Recovery of neurosensory function following orthognathic surgery. *J Oral Maxillofac Surg* 48: 124–134.
- Kerstens HC, Tuinzing DB & van der Kwast WA (1989) Temporomandibular joint symptoms in orthognathic surgery. *J Craniomaxillofac Surg* 17: 215–218.
- Kerstens HC, Tuinzing DB, Golding RP & van der Kwast WA (1990) Condylar atrophy and osteoarthritis after bimaxillary surgery. *Oral Surg Oral Med Oral Pathol* 69: 274–280.
- Kikuta T, Hara I, Seto T, Yoshioka I, Nakashima T & Yasumitsu C (1994) Evaluation of masticatory function after sagittal split ramus osteotomy for patients with mandibular prognathism. *Int J Adult Orthod Orthognath Surg* 9: 9–17.
- Kiyak HA, Hohl T, Sherrick P, West RA, McNeill RW & Bucher F (1981) Sex differences in motives for and outcomes of orthognathic surgery. *J Oral Surg* 39: 757–764.
- Kiyak HA, West RA, Hohl T & McNeill RW (1982) The psychological impact of orthognathic surgery: A 9-month follow-up. *Am J Orthod* 81: 404–412.
- Kiyak HA, McNeill RW, West RA, Hohl T & Heaton PJ (1986) Personality characteristics as predictors and sequelae of surgical and conventional orthodontics. *Am J Orthod* 89: 383–392.
- Kiyak HA & Bell R (1991) Psychosocial Considerations in Surgery and Orthodontics. In: Proffit WR & White RP Jr (eds) *Surgical-Orthodontic Treatment*. St. Louis: Mosby Year Book, p.71–91.
- Kufner J (1971) Four-year experience with major maxillary osteotomy for retrusion. *Journal of Oral Surgery* 29: 549–553.
- Kuttilla M, Niemi PM, Kuttilla S, Alanen P & Le Bell Y (1998) TMD treatment need in relation to age, gender, stress, and diagnostic subgroup. *J Orofacial Pain* 12: 67–74.
- Kuttilla M (1998) Treatment need for temporomandibular disorders in adults. A longitudinal study. (dissertation) *Annales Universitatis Turkuensis, D* 291: 10–24.
- Köle H (1959) Surgical operations on the alveolar ridge to correct occlusal abnormalities. *Oral Surg Oral Med Oral Pathol* 12: 277–288.
- Lanigan DT (1988) Injuries to the internal carotid artery following orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 4: 215–220.
- Lanigan DT (1995) Wound healing after multisegmental LeFort I osteotomy and transection of the descending palatine vessels (discussion). *J Oral Maxillofac Surg* 53: 1433–1434.
- Lanigan D, Hey J & West R (1990a) Major vascular complications of orthognathic surgery: Hemorrhage associated with LeFort I osteotomies. *J Oral Maxillofac Surg* 48: 561–573.
- Lanigan D, Hey J & West R (1990b) Aseptic necrosis following maxillary osteotomies: Report of 36 cases. *J Oral Maxillofac Surg* 48: 142–156.
- Lanigan D, Hey J & West R (1991a) Hemorrhage following mandibular osteotomies: A report of 21 cases. *J Oral Maxillofac Surg* 49: 713–724.
- Lanigan D, Hey J & West R (1991b) Major vascular complications of orthognathic surgery: False aneurysms and arteriovenous fistulas following orthognathic surgery. *J Oral Maxillofac Surg* 49: 571–577.
- Lanigan DT & West RA (1990) Aseptic necrosis of the mandible: Report of two cases. *J Oral Maxillofac Surg* 48: 296–300.

- Lanigan DT, Romanchuk K & Olson CK (1993) Ophthalmic complications associated with orthognathic surgery. *J Oral Maxillofac Surg* 51: 480–494.
- Laskin DM, Ryan WA & Greene CS (1986) Incidence of temporomandibular symptoms in patients with major skeletal malocclusions: A survey of oral and maxillofacial surgery training programs. *Oral Surg Oral Med Oral Pathol* 61: 537–541.
- Laufer D, Glick D, Gutman D & Sharon A (1976) Patient motivation and response to surgical correction of prognathism. *Oral Surg Oral Med Oral Pathol* 41: 309–313.
- LeBell Y, Lehtinen R, Peltomäki T & Peltola J (1993) Function of masticatory system after surgical-orthodontic correction of maxillomandibular discrepancies. *Proc Finn Dent Soc* 89: 101–107.
- Lieberman MA, Gazit E, Fuchs C & Lilos P (1985) Mandibular dysfunction in 10–18 year old school children as related to morphological malocclusion. *J Oral Rehab* 12: 209–214.
- Link JJ & Nickerson JW (1992) Temporomandibular joint internal derangements in an orthognathic surgery population. *Int J Adult Orthod Orthognath Surg* 7: 161–169.
- Lombardo GA, Karakourtis MH & White RP Jr (1994) The impact of clinical practice patterns on hospital charges for orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 9: 251–256.
- Lopez-Gavito G, Wallen TR, Little RM & Joondeph DR (1985) Anterior open-bite malocclusion: a longitudinal 10-year postretention evaluation of orthodontically treated patients. *Am J Orthod* 87: 175–186.
- Lous I & Olesen J (1982) Evaluation of pericranial tenderness and oral function in patients with common migraine, muscle contraction headache and 'combination headache'. *Pain* 12: 385–393.
- Louis PJ, Waite PD & Austin RB (1993) Long-term skeletal stability after rigid fixation of LeFort I osteotomies with advancements. *Int J Oral Maxillofac Surg* 22: 82–86.
- Lovius BBJ, Jones RB, Pospisil OA, Reid D, Slade PD & Wynne THM (1990) The specific psychosocial effects of orthognathic surgery. *J Craniomaxillofac Surg* 18: 339–342.
- Luke DA & Lukas PW (1985) Chewing efficiency in relation to occlusal and other variations in the natural human dentition. *Br Dent J* 159: 401–403.
- Macgregor FC (1981) Patient dissatisfaction with results of technically satisfactory surgery. *Aesthetic Plast Surg* 5: 27–32.
- Magnusson T, Ahlborg G, Finne K, Nethander G & Svartz K (1986) Changes in temporomandibular joint pain-dysfunction after surgical correction of dentofacial anomalies. *Int J Oral Maxillofac Surg* 15: 707–714.
- Magnusson T, Ahlborg G & Svartz K (1990) Function of the masticatory system in 20 patients with mandibular hypo- or hyperplasia after correction by a sagittal split osteotomy. *Int J Oral Maxillofac Surg* 19: 289–293.
- Magnusson T, Egermark I & Carlsson GE (2000) A longitudinal epidemiological study of signs and symptoms of temporomandibular disorders from 15 to 35 years of age. *J Orofac Pain* 14: 310–319.
- Martis C & Karabouta I (1984) Infection after orthognathic surgery, with and without preventive antibiotics. *Int J Oral Surg* 13: 490–494.
- Mehra P, Cottrell DA, Caiazzo A & Lincoln R (1999) Life-threatening, delayed epistaxis after surgically assisted rapid palatal expansion: A case report. *J Oral Maxillofac Surg* 57: 201–204.
- Meningaud J-P, Benadiba L, Servant J-M, Herve C, Bertrand J-C & Pelicier Y (2001) Depression, anxiety and quality of life among scheduled cosmetic surgery patients: multicentre prospective study. *J Craniomaxillofac Surg* 29: 177–180.
- Merkx MAW & Van Damme PA (1994) Condylar resorption after orthognathic surgery. Evaluation of treatment in 8 patients. *J Craniomaxillofac Surg* 22: 53–58.
- Moening JE, Bussard DA, Lapp TH & Garrison BT (1990) Comparison of relapse in bilateral sagittal split osteotomies for mandibular advancement: rigid internal fixation (screws) versus inferior border wiring with anterior skeletal fixation. *Int J Adult Orthod Orthognath Surg* 5: 175–182.
- Moloney F & Worthington P (1981) The origin of the LeFort I maxillary osteotomy. Cheever's operation. *J Oral Surg* 39: 731–734.

- Motegi E, Miyazaki H, Ogura I, Konishi H & Sebata M (1992) An orthodontic study of temporomandibular joint disorders. Part I: Epidemiological research in Japanese 6–18 year-olds. *Angle Orthod* 62: 249–255.
- Moore KE, Gooris PJJ & Stoelinga PJW (1991) The contributing role of condylar resorption to skeletal relapse following mandibular advancement surgery. Report of 5 cases. *J Oral Maxillofac Surg* 49: 448–460.
- Nagamine T, Kabayashi T, Hanada K & Nakajima T (1986) Satisfaction of patients following surgical-orthodontic correction of skeletal Class III malocclusions. *J Oral Maxillofac Surg* 44: 944–948.
- Nagler RM, Peled M & Laufer D (1996) Prolonged dysphagia after orthognathic surgery: Report of a case and review of the literature. *J Oral Maxillofac Surg* 54: 523–525.
- National Institutes of Health Technology Assessment Conference Statement: Management of temporomandibular disorders, April 29-May 1, 1996 (1997) *Oral Surg Oral Med Oral Pathol* 83: 177–183.
- Neuwirth BR, White RP, Collins ML & Phillips C (1992) Recovery following orthognathic surgery and autologous blood transfusion. *Int J Adult Orthod Orthognath Surg* 7: 221–228.
- Nitzan DW & Dolwick MF (1989) Temporomandibular joint fibrous ankylosis following orthognathic surgery: report of eight cases. *Int J Adult Orthod Orthognath Surg* 4: 7–11.
- Nurminen L, Pietilä T & Vinkka-Puhakka H (1999) Motivation for and satisfaction with orthodontic-surgical treatment: a retrospective study of 28 patients. *Eur J Orthod* 21: 79–87.
- Obwegeser H (1969) Surgical correction of small or retrodisplaced maxillae. *J Plast Reconstr Surg* 44: 351–365.
- Obwegeser H (1970) Die einzeitige Vorbewegung des Oberkiefers und Rückbewegung des Unterkiefers zur Korrektur der extremen 'Progenie'. *Schweiz Mschr Zahnheilk* 80: 305. In: Steinhauser EW (1996) Historical development of orthognathic surgery. *J Craniomaxillofac Surg* 24: 195–204.
- Olson RE & Laskin DM (1980) Expectations of patients from orthognathic surgery. *J Oral Surg* 38: 283–285.
- Onizawa K, Schmelzeisen R & Vogt S (1995) Alteration of temporomandibular joint symptoms after orthognathic surgery: comparison with healthy volunteers. *J Oral Maxillofac Surg* 53: 117–121.
- O'Ryan F & Epker BN (1984) Temporomandibular joint function and morphology: Observations on the spectra of normalcy. *Oral Surg Oral Med Oral Pathol* 58: 272–279.
- Ostler S & Kiyak HA (1991) Treatment expectations versus outcomes among orthognathic surgery patients. *Int J Adult Orthod Orthognath Surg* 6: 247–255.
- Pepersack WJ & Chausse JM (1978) Long term follow-up of the sagittal splitting technique for correction of mandibular prognathism. *J Maxillofac Surg* 6: 117–140.
- Perko M (1972) Maxillary sinus and surgical movement of maxilla. *Int J Oral Surg* 1: 177–184.
- Permert L, Karlander EL & Wilhelm E (1998) Treatment of malocclusions in children and adolescents at a Public Dental Service clinic in Sweden: extent and cost. *Swed Dent J* 22: 187–193.
- Pertchuk MJ & Whitaker LA (1982) Social and psychological effects of craniofacial malformations in childhood. *Clin Plast Surg* 9: 297–306.
- Pertchuk MJ & Whitaker LA (1985) Psychosocial adjustment and craniofacial malformations in childhood. *Plast Reconstr Surg* 75: 177–184.
- Pertchuk MJ & Whitaker LA (1987) Psychosocial considerations in craniofacial deformity. *Clin Plast Surg* 14: 163–168.
- Peterson LJ (1990) Antibiotic prophylaxis against wound infections in oral and maxillofacial surgery. *J Oral Maxillofac Surg* 48: 617–620.
- Phillips C, Turvey TA & McMillian A (1989) Surgical orthodontic correction of mandibular deficiency by sagittal osteotomy: Clinical and cephalometric analysis of 1-year data. *Am J Orthod Dentofac Orthop* 96: 501–506.
- Phillips C, Broder HL & Bennett ME (1997) Dentofacial disharmony: Motivations for seeking treatment. *Int J Adult Orthod Orthognath Surg* 12: 7–15.

- Pogrel MA & Scott P (1994) Is it possible to identify psychologically “bad risk” orthognathic surgery patient preoperatively? *Int J Adult Orthod Orthognath Surg* 9: 105–110.
- Proffit WR & Fields HW WL (1983) Occlusal forces in normal- and long-face adults. *J Dent Res* 62: 571–574.
- Proffit WR, Turvey TA, Fields HW & Phillips C (1989) The effect of orthognathic surgery on occlusal force. *J Oral Maxillofac Surg* 47: 457–463.
- Proffit WR & White RP Jr (1991) The need for surgical-orthodontic treatment. In: *Surgical-Orthodontic Treatment*. Mosby, St. Louis, p.2–23.
- Proffit WR, Phillips C, Prewitt JW & Turvey TA (1991a) Stability after surgical-orthodontic correction of skeletal Class III malocclusion. 2. Maxillary advancement. *Int J Adult Orthod Orthognath Surg* 6: 71–80.
- Proffit WR, Phillips C & Turvey TA (1991b) Stability after surgical-orthodontic correction of skeletal Class III malocclusion. 3. Combined maxillary and mandibular procedures. *Int J Adult Orthod Orthognath Surg* 6: 211–225.
- Proffit WR, Tulloch JFC & Medland PH (1992) Surgical versus orthodontic correction of skeletal Class II malocclusion in adolescents: Effects and indications. *Int J Adult Orthod Orthognath Surg* 7: 209–220.
- Proffit WR, Turvey TA & Phillips C (1996) Orthognathic surgery: a hierarchy of stability. *Int J Adult Orthod Orthognath Surg* 11: 191–204.
- Proffit WR, Fields HW Jr & Moray LJ (1998) Prevalence of malocclusion and orthodontic treatment need in the United States: Estimates from the NHANES III survey. *Int J Adult Orthod Orthognath Surg* 13: 97–106.
- Raphael KG, Marbach JJ & Touger-Decker R (2002) Dietary fiber intake in patients with myofascial face pain. *J Orofac Pain* 16: 39–47.
- Rauhala K, Oikarinen KS, Järvelin MR & Raustia A (2000) Facial pain and temporomandibular disorders: an epidemiologic study of the Northern Finland 1966 Birth Cohort. *Cranio* 18: 40–46.
- Reynders RM (1990) Orthodontics and temporomandibular disorders: a review of the literature (1966–1988). *Am J Orthod Dentofac Orthop* 97: 463–471.
- Riley RW, Powell NB & Guilleminault C (1993) Obstructive sleep apnea syndrome: A review of 306 consecutively treated surgical patients. *Otolaryngol Head Neck Surg* 108: 117–125.
- Riolo ML, Brandt D & TenHave TR (1987) Associations between occlusal characteristics and signs and symptoms of TMJ dysfunction in children and young adults. *Am J Orthod Dentofac Orthop* 92: 467–477.
- Rittersma J (1989) Patient information and patient preparation in orthognathic surgery. The role of an information brochure. A medical audit study. *J Craniomaxillofac Surg* 17:278–279.
- Roberts CA, Tallents RH, Katzberg RW, Sanchez-Woodworth RE, Espeland MA & Handelman SL (1987) Comparison of internal derangements of the TMJ with occlusal findings. *Oral Surg Oral Med Oral Pathol* 63: 645–650.
- Rodrigues-Garcia RCM, Sakai S, Rugh JD, Hatch JP, Tiner BD, van Sickels JE, Clark GM, Nemeth DZ & Bays RA (1998) Effects of major Class II occlusal corrections on temporomandibular signs and symptoms. *J Orofac Pain* 12: 185–192.
- Sadovski C & Beyole EA (1980) Long-term status of temporomandibular joint function and functional occlusion after orthodontic treatment. *Am J Orthod* 78: 201–212.
- Sailer HF, Haers PE & Grätz KW (1999) The LeFort I osteotomy as a surgical approach for removal of tumours of the midface. *J Craniomaxillofac Surg* 27: 1–6.
- Salonen L, Hellden L & Carlsson GE (1990) Prevalence of signs and symptoms of dysfunction in the masticatory system: An epidemiological study in an adult Swedish population. In: Kuttilla M (1998) Treatment need for temporomandibular disorders in adults. A longitudinal study. (dissertation) *Annales Universitatis Turkuensis*, D 291: 10–24.
- Scheerlinck JPO, Stoelinga PJW, Blijdorp PA, Brouns JJA & Nijs MLL (1994) Sagittal split advancement osteotomies stabilized with miniplates. A 2–5 year follow-up. *Int J Oral Maxillofac Surg* 23: 127–131.
- Schellhas KP (1989) Unstable Occlusion and Temporomandibular Joint Disease. *J Clin Orthod* 23: 332–337.

- Schellhas KP, Wilkes CH, Fritts HM, Omlie MR & Lagrotteria LB (1989) MR of osteochondritis dissecans and avascular necrosis of the mandibular joint. *Am J Roentgenol* 152: 551–560.
- Schendel SA & Epker BN (1980) Results after mandibular advancement surgery: An analysis of 87 cases. *Journal of Oral Surgery* 38: 265–282.
- Schneider S & Witt E (1991) Funktionelle Befunde vor und nach einer kombiniert kieferorthopädisch-kieferchirurgischen Behandlung von Angle-Klasse-II- Patienten. *Fortschr Kieferorthop* 52: 51–59.
- Schuchardt K (1942) Ein Beitrag zur chirurgischen Kieferorthopädie unter Berücksichtigung ihrer Bedeutung für die Behandlung angeborener und erworbener Kieferdeformitäten bei Soldaten. *Dtsch Zahn Mund Kieferheil* 9:73–89.
- Seddon HJ (1943) Three types of nerve injury. In: Ylikontiola L (2002) Neurosensory disturbance after bilateral sagittal split osteotomy. (dissertation) *Acta Univ Oul D* 685: 32–33.
- Seligman DA & Pullinger AG (1991) The role of functional occlusal relationships in temporomandibular disorders: A review. *J Craniomandib Disord* 5: 265–279.
- Sipilä K, Zitting P, Siira P, Laukkanen P, Järvelin MR, Oikarinen KS & Raustia AM (2002) Temporomandibular disorders, occlusion, and neck pain in subjects with facial pain: a case-control study. *Cranio* 20: 158–164.
- Smith GC, Moloney FB & West RA (1985) Mandibular advancement surgery: A study of the lower border wiring technique for osteosynthesis. *Oral Surg Oral Med Oral Pathol* 60:467–475.
- Smith V, Williams B & Stapleford R (1992) Rigid internal fixation and the effects on the temporomandibular joint and masticatory system: a prospective study. *Am J Orthod Dentofac Orthop* 102: 491–500.
- Solberg WK, Bibb CA, Nordström BB & Hansson TL (1986) Malocclusion associated with temporomandibular joint changes in young adults at autopsy. *Am J Orthod* 89: 326–330.
- Sonnesen L, Bakke M & Solow B (1998) Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion. *Eur J Orthod* 20: 543–559.
- Sostmann M, Meyer J & Berten JL (1991) TMJ function following orthognathic surgery. *Dtsch Stomatol* 41: 487–489.
- Steinhäuser EW (1996) Historical development of orthognathic surgery. *J Craniomaxillofac Surg* 24: 195–204.
- Stewart TD & Sexton J (1987) Depression: A possible complication of orthognathic surgery. *J Oral Maxillofac Surg* 45: 847–851.
- Storum KA & Bell WH (1984) Hypomobility after maxillary and mandibular osteotomies. *Oral Surg Oral Med Oral Pathol* 57: 7–12.
- Suuronen R, Haers PE, Lindqvist C & Sailer HF (1999) Update on bioresorbable plates in maxillofacial surgery. *Facial Plast Surg* 15: 61–72.
- Tasanen A, Ylipaavalniemi P, Haavikko K (1981) Closed condylotomy in the treatment of mandibular prognathism. *Proc Finn Dent Soc* 77:312.317.
- Teerijoki-Oksa T, Jääskeläinen S, Forssell K, Virtanen A & Forssell H (2003) An evaluation of clinical and electrophysiologic tests in nerve injury diagnosis after mandibular sagittal split osteotomy. *Int J Oral Maxillofac Surg* 32: 15–23.
- Throckmorton GS, Johnston CP, Gonyea WJ & Bell WH (1984) A preliminary study of biomechanical changes produced by orthognathic surgery. *J Prosth Dent* 51: 252–261.
- Throckmorton GS, Ellis E III & Sinn DP (1995) Functional characteristics of retrognathic patients before and after mandibular advancement surgery. *J Oral Maxillofac Surg* 53: 898–908.
- Thyne GM, Ferguson JW & Pilditch FD (1992) Endotracheal tube damage during orthognathic surgery. *Int J Oral Maxillofac Surg* 21:80.
- Tobiasen JM, Levy J, Carpenter MA & Hiebert JM (1987) Type of facial cleft, associated congenital malformations and parents' ratings of school and conduct problems. *Cleft Palate Journal* 24: 209–215.
- Trauner R & Obwegeser HL (1957) The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. *Oral Surg* 10: 787–792.
- Tucker MR (1995) Orthognathic surgery versus orthodontic camouflage in the treatment of mandibular deficiency. *J Oral Maxillofac Surg* 53: 572–578.

- Tucker MR & Thomas PM (1986) Temporomandibular pain and dysfunction in the orthodontic surgical patient: rationale for evaluation and treatment sequencing. *Int J Adult Orthod Orthognath Surg* 1: 11–22.
- Turvey TA & White RP, Jr (1991) Maxillary Surgery. In: *Surgical-Orthodontic Treatment*. Mosby, St. Louis, p.248–263.
- Turvey TA & Fonseca RJ (1980) The anatomy of internal maxillary artery in the pterygopalatine fossa: its relationship to maxillary surgery. *J Oral Surg* 38: 92–95.
- Upton GL, Scott RF & Hayward JR (1984) Major maxillo-mandibular malrelations and temporomandibular joint pain-dysfunction. *J Prosthet Dent* 51: 686–690.
- Wadhwa L, Utreja A & Tewari A (1993) A study of clinical signs and symptoms of temporomandibular dysfunction in subjects with normal occlusion, untreated, and treated malocclusions. *Am J Orthod Dentofac Orthop* 103: 54–61.
- Vallino L (1990) Speech, velopharyngeal function, and hearing before and after orthognathic surgery. *J Oral Maxillofac Surg* 48: 1274–1281.
- Vallon D & Nilner M (1997) A longitudinal follow-up of the effect of occlusal adjustment in patients with craniomandibular disorders. *Swed Dent J* 21: 85–91.
- Van Merkesteyn JPR, Groot RH, Van Leeuwen R & Kroon FHM (1987) Intra-operative complications in sagittal and vertical ramus osteotomies. *Int J Oral Maxillofac Surg* 16: 665–670.
- Van Sickels JE & Richardson DA (1996) Stability of orthognathic surgery: a review of rigid fixation. *Brit J Oral Maxillofac Surg* 34: 279–285.
- Wanman A (1987) Craniomandibular disorders in adolescents. A longitudinal study in an urban Swedish population. *Swed Dent J Suppl* 44: 1–61.
- Van Sickels JE, Hatch JP, Dolce C, Bays RA & Rugh JD (2002) Effects of age, amount of advancement, and genioplasty on neurosensory disturbance after a bilateral sagittal split osteotomy. *J Oral Maxillofac Surg* 60: 1012–1017.
- Westermarck A (1999) On inferior alveolar nerve function after sagittal split osteotomy of the mandible. (dissertation) Kongl Karolinska Medico Chir Inst, Stockholm, 10–13.
- Westermarck A, Shayeghi F & Thor A (2000) Temporomandibular dysfunction in 1516 patients before and after orthognathic surgery. *Int J Adult Orthod Orthognath Surg* 16: 145–151.
- White RP, Peters PB, Costich ER & Page HL Jr (1969) Evaluation of sagittal split-ramus osteotomy in 17 patients. *Journal of Oral Surgery* 27: 851–855.
- White CS & Dolwick MF (1992) Prevalence and variance of temporomandibular dysfunction in orthognathic surgery patients. *Int J Adult Orthod Orthognath Surg* 7: 7–14.
- Victorin L, Hillerström K & Sörenson S (1969) Biological and psycho-social factors in patients with malformations of the jaws: A study of 95 patients prior to treatment. *Scand J Plast Reconstr Surg* 3: 138–143.
- Will LA, Joondeph DR, Hohl TH & West RA (1984) Condylar position following mandibular advancement: its relationship to relapse. *J Oral Maxillofac Surg* 42: 578–588.
- Willmar K, Hogeman K-E & Thiseus S (1979) Sagittal split osteotomy in our experience. A follow-up study of 100 operated cases. *Scand J Plast Reconstr Surg* 13: 445–452.
- Wolfed LM (1998) Discussion. In: Schultes G, Gaggl A & Kärcher H (1998) Periodontal disease associated with interdental osteotomies after orthognathic surgery. *J Oral Maxillofac Surg* 56: 414–417.
- Wyatt WM (1997) Sagittal ramus split osteotomy: literature review and suggested modification of technique. *Br J Oral Maxillofac Surg* 35: 137–141.
- Ylikontiola L (2002) Neurosensory disturbance after bilateral sagittal split osteotomy. (dissertation) *Acta Univ Oul D* 685: 32–33.
- Zarrinkelk HM, Throckmorton GS, Ellis E III & Sinn DP (1996) Functional and morphologic changes after combined maxillary intrusion and mandibular advancement surgery. *J Oral Maxillofac Surg* 54: 828–837.
- Zhou YH, Hägg U & Rabie ABM (2001) Concerns and motivations of skeletal Class III patients receiving orthodontic-surgical correction. *Int J Adult Orthod Orthognath Surg* 16:7–17.

Zijderveld SA, Smeele LE, Kostense PJ & Tuinzing DB (1999) Preoperative antibiotic prophylaxis in orthognathic surgery: A randomized, double blind, and placebo-controlled clinical study. *J Oral Maxillofac Surg* 57: 1403–1406.