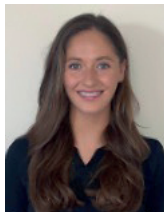

Caroline McElroy

Andrew DiBiase

Limitations of orthodontic treatment: Class III camouflage

Abstract: Class III malocclusion treatment planning in the non-growing patient can represent a challenge. The options of whether to attempt orthodontic camouflage or to treat with orthognathic surgery are affected by numerous factors, including the severity of the underlying skeletal relationship, the dento-alveolar compensation already present, the facial aesthetics, the patient's concerns and expectations, and the anatomical limits of orthodontic tooth movement. Numerous studies have tried to provide guidance by looking at the differences between groups of patients to determine whether they should be treated orthodontically or surgically. However, owing to the retrospective nature of these studies and their heterogeneity, they prove less helpful than desired. In this narrative review, the authors will look at these studies to provide some guidance for the orthodontist.

CPD/Clinical Relevance: Treatment planning in Class III malocclusions can be challenging owing to the numerous factors that must be considered.

Ortho Update 2024; 17: 143–154

A Class III malocclusion can be defined using Angle's molar relationship and is usually associated with a Class III incisor relationship: the lower incisor edges occluding anteriorly to the cingulum plateau of the upper incisors.[1] The reported prevalence of Class III malocclusion ranges from 0% to 39%, depending on ethnic population, with a global mean of 6–11%.[2–4] It is more prevalent in East Asian and Middle Eastern populations, with lower numbers reported in European, African and South Asian populations.[2]

Class III malocclusion is not just one entity, but presents with a varied phenotype, making the management difficult. It can be characterized by a number of dental and skeletal features, including mandibular prognathism, maxillary hypoplasia, acute cranial base angle, shorter anterior cranial base, long posterior cranial base, protrusive mandibular dentition, retrusive maxillary dentition or combinations of any of the above.[5–9] The management of Class III malocclusions is complicated further by uncertainty pertaining to growth. Pubertal growth in patients with a Class III malocclusion appears to occur later and go on longer than in their Class I peers.[10,11] Combined, these factors complicate treatment planning for Class III malocclusions.

Treatment options in pre-adolescent patients may include the use of protraction headgear with or without skeletal anchorage, which has been shown to be effective.[12] In adolescent patients, the use of skeletal anchorage in the form of bone-anchored maxillary protraction (BAMP) has shown impressive results. Still, these lessen when subjected to the rigors of a well-run clinical study.[13,14] Therefore, owing to the uncertainty of growth and the unpredictability of interceptive treatment, historically in the UK, there has been a policy of watch and wait until the end of adolescent growth when definitive treatment decisions can be made. Even then, making a decision can be difficult because it is dependent on numerous factors, including the underlying malocclusion, the patient's concerns and expectations, and what is physically possible in terms of orthodontic tooth movement. This results in a lack of consensus between clinicians on the management of Class III malocclusions.[15] This narrative review focuses on this controversial area, the treatment planning for Class III in young adults and the limitations of orthodontic treatment.

Caroline McElroy, BDS, Specialist Registrar in Orthodontics; **Andrew DiBiase**, BDS (Hons), FDS, MSc, MOrth, FOrth, RCS Eng, Consultant Orthodontist; East Kent Hospitals University NHS Foundation Trust, Kent.
email: andrewdibiase@nhs.net

Features that suit OC treatment	Features for which OC treatment should be avoided
Skeletal Class I or mild Class III relationship	Retroclined lower incisors
Minimal dento-alveolar compensation (ideally proclined lower incisors, upright/ retroclined upper incisors)	Proclined upper incisors
Anterior displacement on closing, with the patient able to achieve edge-to-edge incisor relationship in the retruded contact position (RCP)	Reduced overbite
Average or increased overbite	Increased lower face height
Average or reduced lower face height	Moderate to severe Class III skeletal base relationship
Normal soft tissue features (nose, lips, chin)	No anterior displacement on closing from RCP into ICP
No transverse skeletal problems	Significant Class III molar relationship

Table 1. Clinical features used to define the limits of orthodontic camouflage (OC) in Class III cases.

Management of Class III: what are the options?

Essentially, there are two treatment alternatives for Class III malocclusion in the non-growing patient.

Orthodontic camouflage (OC)

This means accepting the underlying skeletal relationship and orthodontically repositioning the dentition to achieve a Class I incisor relationship, hence camouflaging the skeletal discrepancy. The concepts of camouflage treatment were introduced to orthodontics in the 1930s, coinciding with the development of cephalometrics and the belief that facial growth was primarily genetically determined and, therefore, immutable to any orthodontic treatment.

Camouflage treatment can be successful in cases where the skeletal discrepancy is mild to moderate, with good soft tissue aesthetics, no significant asymmetry and an adequate overbite prior to treatment (Table 1). In camouflaging a Class III malocclusion, the effects are dento-alveolar, primarily proclination of the maxillary incisors and retroclination of the mandibular incisors, which results in the lower lip being slightly less protrusive.[16–22] In cases that start with a protrusive lower lip, this can be beneficial[23] (Figure 1). Tooth movement to camouflage a severe skeletal discrepancy may be physically impossible,[24] or could result in an unacceptable compromise to the soft tissue profile as the over-retraction of lower incisors to create a positive overjet, can result in relative prominence of the chin (Figure 2).

Orthognathic surgery (OGN)

With the introduction of the sagittal split osteotomy[25] and later the Le Fort 1 osteotomy,[26] the scope and range of what could be achieved dentally and skeletally has increased dramatically. Surgical correction results in greater skeletal change and an improvement in the sagittal relationship with a corresponding improvement in the soft tissue as measured by the position of the lips to the E-plane (the line drawn from nasal tip to chin point with the upper lip ideally 4 mm behind and the lower 2 mm behind) and the naso-labial angle.[19,21,22] Clinically, patients treated with OGN tend to have less retroclined lower incisors, a small reduction in horizontal chin projection, a deeper labiomental fold and less retrusive lips. However, increased upper incisor proclination during treatment is found in surgical and camouflage patients, albeit more in OC patients.[27,28] This inadequate decompensation has been found to limit the outcome of OGN.[27]

Both treatment modalities appear to give stable results although slightly higher

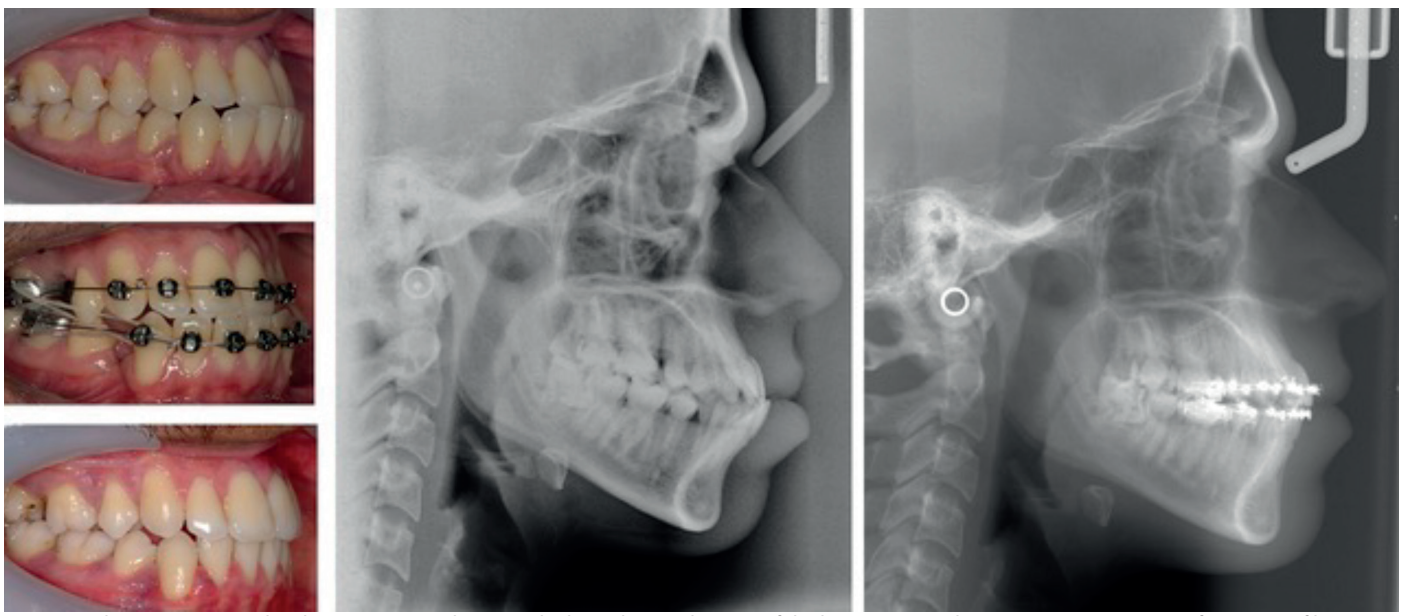

Figure 1. Class III case treated with extractions and OC mostly through retroclination of the lower incisors showing improvement in soft tissue profile because the lower lip became less protrusive.

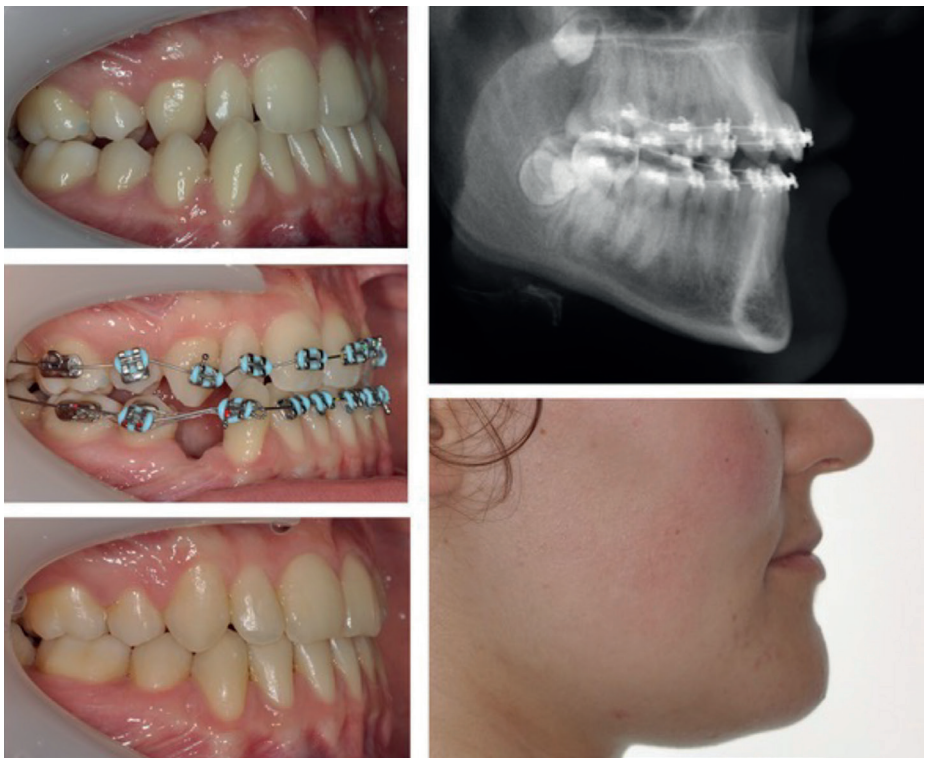

Figure 2. OC for Class III malocclusion with retroclination of the lower incisors and lower lip resulting in relative prominence of the chin.

skeletal relapse has been reported with OGN than for OC in borderline Class III patients, reflecting the treatment they had.[17] Greater functional problems, such as pain and clicking of the temporomandibular joint and restriction in mouth opening, have also been reported post-treatment in OGN patients compared to OC patients.[17]

The decision whether a patient is treated with OC or OGN must be made before treatment begins because the tooth movement to prepare a patient for OGN is in the opposite direction to orthodontic treatment for OC (i.e. decompensation as opposed to further dento-alveolar compensation). Like most decisions in orthodontics, patients on the extremes are fairly straightforward to plan. It is the borderline patient, where the characteristics on which the choice of OC or OGN is based are similar, that represents a challenge.[29] Proffit defined an 'envelope of discrepancy' that supposedly described the limits of orthodontic tooth movement for growth modification, orthodontic tooth movement and surgery.[30]

However, the treatment decision to attempt to camouflage a Class III malocclusion is not dependent on a single measure, but rather numerous factors and, therefore, can be difficult to make. The following parameters need to be considered.

Skeletal

The severity of the underlying malocclusion is one of the key factors in whether it is desirable, or indeed possible, to attempt OC in a Class III malocclusion. While this can be assessed and described clinically, research has primarily been based on the use of cephalometrics. Numerous, generally retrospective, studies have tried to define the limitations of orthodontic treatment for Class III malocclusions.[28,31–37] These usually involve the assessment of a series of cases to define them as either treatable, with or without recourse to OGN, or cases that had been or could be successfully treated with either modality. Dividing the samples into participants who were or should be ideally treated either with OC or OGN, simple univariate analyses or multivariate analysis, generally in the form of discriminant analysis, a statistical technique for categorizing data into groups, is used to look at the cephalometric dental and skeletal differences between the two groups in hope of either providing a measurement that would provide a 'threshold' value or an algorithm created from a number of measures that provides an indicator of whether OC or OGN is the appropriate treatment approach (Table 2)

As Class III is not a single entity and has numerous phenotypes, unsurprisingly these studies have thrown out a variety of parameters that seem to influence treatment decisions. Those most commonly reported, where there was a difference between the OC and OGN groups pre-treatment, were the angulation of the lower incisors to the mandibular plane, ANB, Wits, inter-incisal angle, Holdaway angle, SNB, the maxillary/mandibular unit length ratio (M/M) and the gonial angle. No studies found a pre-treatment difference between the OC and OGN groups in relation to the sagittal position of the maxilla as measured by SNA, and only one found a difference in relation to the angulation of the maxillary incisors, with those in the OC group being more retroclined by 5°.[35] This would imply the determining factors seem to be primarily related to the degree of dento-alveolar compensation of lower incisors

Figure 3. A Class III malocclusion was treated with extractions and OC, with retroclined lower incisors and labial recession on the lower right lateral incisor.

Study	Methodology	Findings
Kerr *et al* 1992[30]	40 patients OGN: 20 pre-treatment deemed to need surgery OC: 20 post-treatment successfully treated orthodontically Univariate means testing between groups	These researchers indicated that OGN should be performed for patients with: ANB angle of less than -4° Maxillary/mandibular (M/M) ratio of 0.84 An inclination of the lower incisors to the mandibular of 83° Holdaway angle of 3.5^0
Stellzig-Eisenhauer *et al* 2002[31]	Cross sectional 175 adult patients pre-treatment Group divided into OGN or camouflage by three experienced orthodontists 87 OC 88 OGN Discriminant analysis	Predictive model using four parameters: Wits appraisal SN M/M ratio (maxillary/mandibular ration) Lower gonial angle -1.805 + 0.209 *Wits + 0.044* S-N + 5.689 * M/M ratio - 0.056 *Go lower >-0.023 = OC <-0.023 = OGN 92% correctly classified 86.4% sensitivity 97.7% specificity
Rabie *et al* 2008[32]	Retrospective 25 patients post-treatment. 12 OC 13 OGN Discriminant analysis	Holdaway angle threshold of 12° >12 = OC <12= OGN 72% correctly classified 76.9% sensitivity 66.7% specificity
Benyahia *et al* 2011[33]	Retrospective 47 patients 22 OC 25 OGN Discriminant analysis	15 out of 27 cephalometric parameters different between groups Only one variable could distinguish between groups, the Holdaway angle threshold value of 7.2° H angle <7.2° = OGN H angle >7.2°= OC 87.2% correctly classified Sensitivity 84% Specificity 90.9%
Kochel *et al* 2011[34]	Cross sectional 69 patients pre-treatment Group divided into OGN or camouflages by three experienced orthodontists 28 OC 41 OGN Discriminant analysis	Predictive model using five parameters: ■ Wits appraisal ■ Cranial base angle ■ Maxillary-mandibular ratio ■ Gonial angle ■ Mandibular midline deviation –10.988 +0.243 * Wits + 0.055 * M/M ratio + 0.068 * NSAr – 0.589 * mand MLD. >0.251 = OC <0.251 = OGN 91.3% correctly classified 92.7% sensitivity 89.3% specificity
Tseng *et al* 2011[35]	Retrospective 80 patients 40 OC 40 OGN Receiver operating characteristics (ROC) analysis	14 significantly different measurements Using ROC scoring system of six dichotomized measurements with a cut off of four for patients requiring surgery: -4.73 mm or more reverse overjet Wits ≤-11.18 mm LI-Md plane angle ≤80.8° Mx/Md plane ratio ≤65.9% Overbite ≤-0.18 mm Gonial angle ≥120.8° 88% sensitivity 90% specificity

Martinez *et al* 2017[27]	Retrospective 156 patients 77 OC 79 OGN Parametric statistical testing for comparison between groups pre and post treatment	Wits appraisal, lower incisor inclination and inter-inicisal angle were only statistically significant different measurements between groups before treatment
Eslami *et al* 2018[36]	Retrospective 65 patients moderate skeletal Class III who had undergone treatment 36 OC 29 OGN Discriminant analysis	Holdaway angle threshold of 10.3 and Wits appraisal to be the best parameters to use Holdaway angle <10.3^0 and Wits <-5.8mm = OGN Holdaway angle >10.3^0 and Wits >-5.8mm = OC 81.5% correctly classified 82.8% sensitivity 80.6% specificity

Table 2. Studies looking at the cephalometric parameters that distinguished between Class III cases that could be treated with OC and those that required OGN. Five of the eight studies found the Holdaway angle to be a reliable guide to determine the treatment modality of Class III patients.[3] In 1983, Holdaway defined the H angle as the angle formed by the soft tissue H line and the soft tissue facial plane (soft tissue nasion–soft tissue pogonion tangent to the upper lip), Na-Pog. Ideally, its value is 100 when facial convexity is normal. This angle quantifies the protrusion of the upper lip relative to the soft tissue profile, and it is independent of the skeletal discrepancy of the bases (ANB angle). Therefore, it is useful for characterizing the profile of borderline Class III skeletal cases in whom aesthetics and facial appearance might be of greater importance than occlusion or skeletal discrepancy. Wits appraisal was another common parameter used in the more recent studies. Three studies used lower incisor inclination to determine the choice of OGN vs orthodontic treatment.

Figure 4. Class III malocclusion treated with OC showing a reduction in incisor showing as upper incisors are proclined.

and the underlying sagittal discrepancy as reflected in the relative degree of mandibular prognathism and the convexity of the profile.

What is also apparent is that the vertical growth pattern is important, with patients exhibiting a hyperdivergent facial form being less amenable to camouflage treatment. This, in part, is accounted for in the Wits analysis, because it uses the functional occlusal plane as its reference line, and this rotates downwards and backwards in cases with an increased maxillary–mandibular planes angle. It is also reflected in the use of the gonial angle in three of the studies as a discriminator between Class III malocclusions that were amenable to OC, and those that would require OGN to treat them. The difficulty of OC in high-angle cases may in part be due to the reduced overbite or anterior open bite that is often found, which any proclination of the upper incisors would worsen. Furthermore, the lower incisors tend to be relatively upright or retroclined, which combined with the narrower symphyseal bone and thinner gingival biotypes often found in such patients, means physically there is less scope for further retroclination and dento-alveolar compensation, because this would result in the loss of labial attachment and predispose to recession (Figure 3).[24]

As well as the A-P and vertical discrepancies inherent in a Class III malocclusion, the transverse relationship also needs to be considered, especially in relation to asymmetry. Kochel *et al* presented an updated model to the one originally proposed by Stellzig-Eisenhauer *et al* that included mandibular deviation.[32,35] This, however, did not increase the accuracy of the prediction of the model.

When the mean measurements reported in these studies are looked at there is a large range, with much crossover between the OC and OGN patient groups and across the studies. It is apparent that there is no single measurement or formulae that can provide the answer (Table 3). One of the inherent problems is that to perform a valid and reliable discriminant analysis, certain assumptions and conditions need to be met, including having a large and representative sample size. The studies listed are all retrospective or cross-sectional and have small sample sizes, which may lead to biased, inaccurate or misleading results. Owing to the selection criteria for inclusion, where there is generally a baseline cut-off to classify a case as Class III, as seen in Table 3, there is a large range in severity. This means that they are not looking primarily at the borderline cases where the treatment planning is difficult, but a wider range of Class III malocclusions, including those on the extremes, where it is easier to make decisions. They also are heterogeneous, using different measurements and samples from different ethnic groups with different cephalometric norms. This makes interpretation difficult, and therefore, the application of the results must be exercised with caution especially when being applied to different ethnic groups.

Soft tissues

In Ackerman and Proffit's classic paper, they defined the treatment limitations in what they described as the soft tissue envelope in which the dentition develops.[38] The soft tissue constraints on orthodontic treatment are as follows:

- The pressures exerted by the lips, cheeks, tongue on the teeth;
- The periodontal attachment apparatus;
- The muscles and connective tissue components of the TMJ;
- The contours of the face.

In Class III cases, this envelope is affected by the underlying skeletal pattern, which can result in dento-alveolar compensation, typically retroclination of the lower incisors and proclination of the uppers. The extent of this will, in part, determine what further orthodontic tooth movements are possible. If the lower incisors are already significantly retroclined, further retroclination may not be advisable or even physically possible.[23]

	OC	OGN
ANB	-3.87–0.49°	-6.9^0 – -2.1°
M/M ratio	0.69–0.93	0.64 –0.83
Wits	-9.67– -4.61 mm	-15.27– -6.80 mm
Holdaway	6.1–14.57°	0.90–10.14°
Gonial angle	119.55–132.2°	123.7–133.30°
UI/Max	112.9–122.58°	112.7–121.6°
UI/SN	102.95–111.76°	106.02–108.74°
LI/Mand	85.4–93.74°	77.07–86.91°

Table 3. Range of the mean measurements reported in the studies in Table 2 for patients classified as treatable with either OC or OGN.

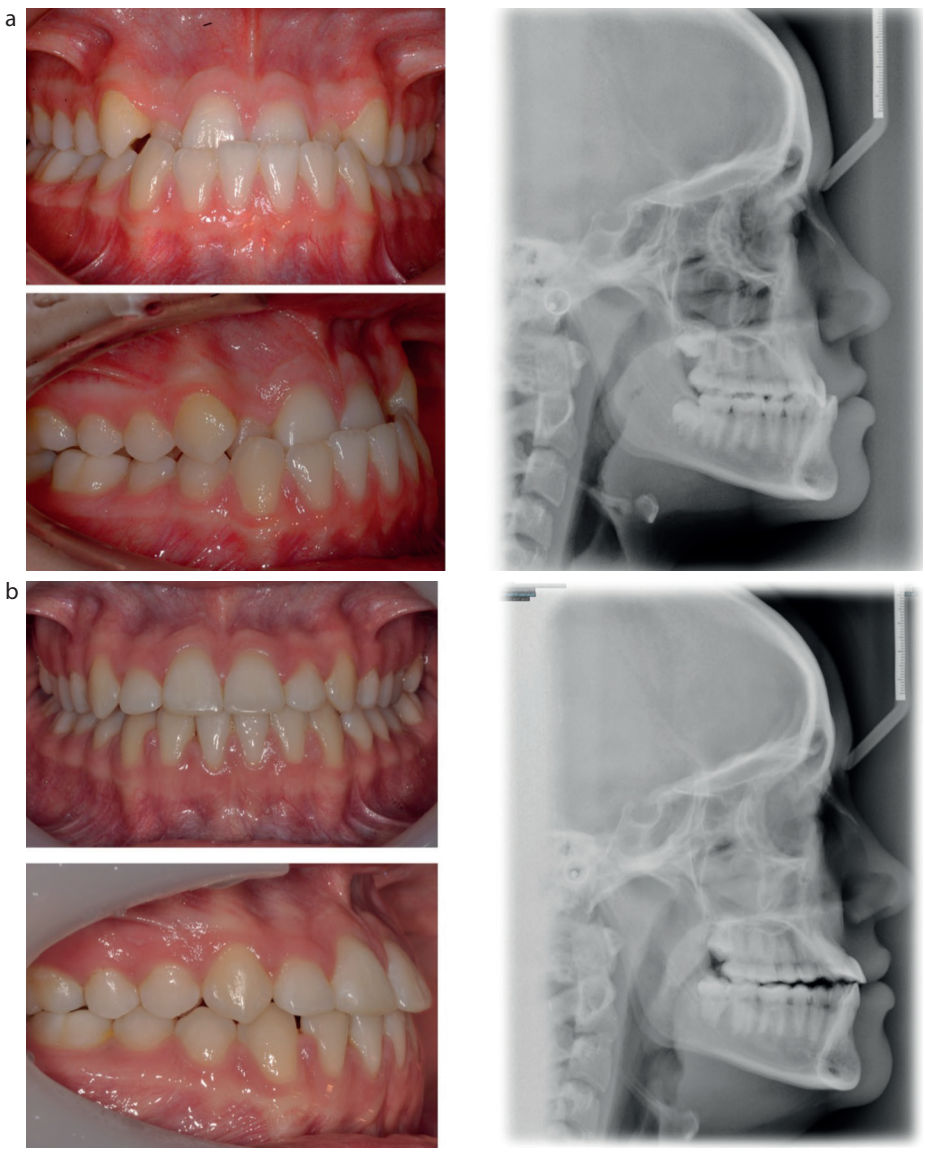

Figure 5. (a,b) Class III malocclusion treated with OC resulting in excessive proclination of the upper incisors.

Facial aesthetics

Facial aesthetics are important to assess and a big determinant for deciding between OGN and OC treatment. Maxillary hypoplasia is associated with paranasal hollowing, flattening of the malar bases, a reduced nasolabial angle and increased scleral show. Mandibular prognathism can result in excessive prominence of the lower lip and chin. There is also a higher incidence of asymmetry in Class III cases, all of which maybe a concern to the patient.

A maxillary hypoplasia can lead to a lack of incisor show at rest and on smiling and, therefore, poor dental aesthetics. OC is unlikely to improve this and indeed can make it worse if the upper incisors are proclined (Figure 4). In cases of mandibular prognathism, retroclination of the lower incisors will result in lower lip retraction, relatively making the chin look more prominent (see Figure 2).[21,22] This is also affected by the form of chin and symphysis, with high-angle, hyperdivergent patients often having thinner symphyses and less prominent, flatter chins. Aesthetically, the lower lip should be as prominent as the chin so any further retraction can result in poor soft tissue aesthetics.

It is, therefore, important to assess the face both in profile and from the front. If there is a good profile in centric relation, this would be an indicator that the case is amenable to treatment with OC.[39] The Holdaway angle can also be used, and this has been found to be an important discriminator between cases that can be treated with OC and those that require OGN. This is the angle formed between the soft tissue plane, soft tissue nasion to soft tissue pogonion, and the H-line, a line drawn from soft-tissue menton tangent to the upper lip.[40] This has an ideal value of 10° when the facial convexity is

normal, lower values being indicative of a skeletal III relationship. Threshold values distinguishing between surgical and non-surgical cases have been reported of 3.5° by Kerr *et al*, 7.2° by Benyachi *et al* and 12° by Rabie *et al*, the latter being above the ideal angle of 10° reported by Holdaway, but representing a Chinese population.[30,32,33] This emphasizes the importance of ethnicity in making these decisions using cephalometric norms determined in European patients.

Figure 6. (a) The patient from Figure 4 with a Class III incisor relationship with large anterior displacement from RCP to ICP. **(b)** The patient underwent OC treatment, starting with a lower removable appliance to open the bite to allow the placement of upper fixed appliance to procline the upper labial segment. **(c)** Case at the end treatment. The Class III incisor relationship was successfully treated. Note the retroclined lower incisors.

Dental

OC treatment for Class III invariably involves proclining the upper incisors and/or retroclining the lowers, increasing dento-alveolar compensation. The limits of this depend on many factors, including the vertical growth pattern, the width and quality of the alveolar bone and the gingival biotype. While it is possible to retrocline the lower incisors a significant degree in the attempt to camouflage a Class III malocclusion, there is a hard and soft tissue limit. The lower incisors are susceptible to recession if retroclined, especially in high-angle Class III cases with a narrow symphysis and pre-existing thin biotype.[41,42] While the risk of recession is less when the upper incisors are proclined, excessive proclination increases the risk of non-axial loading, fremitus and mobility (Figure 5).

Attempts have been made to put cephalometric figures on these limits. Steiner produced his cephalometric 'sticks' that allowed for the modification of the angulation of the upper and lower incisors based on the ANB angle.[43] Tweed based the placement of the lower incisors on the angle between them and the Frankfurt plane, which in turn is influenced by the Frankfurt mandibular planes angle and the vertical growth pattern.[44] Bennett and McLaughlin developed the soft tissue cephalometric analysis (STCA) based on the work of Arnett and Fastlight.[45–47] They stated that the upper incisors could be proclined to 120° to the maxillary plane and the lower retoclined to 80° to the mandibular plane, dependent on the size of the thickness of the symphysis and the amount of bone available.[24] This has been supported by a study looking at the limits of incisor movement in Class III OC cases, which found the maxillary incisors being 120° to the sella-nasion line and the mandibular incisors 80° to the mandibular plane.[18] It may be possible to retrocline the lower incisors more than this, but this should be done with caution owing to the risk of loss of attachment and the impact on facial aesthetics (see Figure 3).[18]

Occlusal

The presence of an anterior displacement from centric relation to centric occlusion is a favourable sign that OC is possible because it indicates the underlying skeletal relationship is only mildly skeletal III or even skeletal I, often described as a pseudo Class III relationship. As long as there has not been excessive dento-alveolar compensation, cases that present with a significant forward displacement are usually amenable to OC (Figure 6).

The buccal segment also needs to be assessed in relation to the molar and canine relationship. Therefore, one of the further parameters suggested by Lin *et al* that indicate a case is treatable with OC is a Class I buccal segment relationship in centric occlusion.[39] If the molar relationship is not Class I but Class III, it does not mean the case could not be treated with OC, but rather that space will be required in the lower arch for retraction of the canines into Class I to achieve a Class I incisor relationship. This can be created with lower arch extractions. This is usually lower premolars (Figures 7 and 8), but lower first molars can be considered especially if they are restored

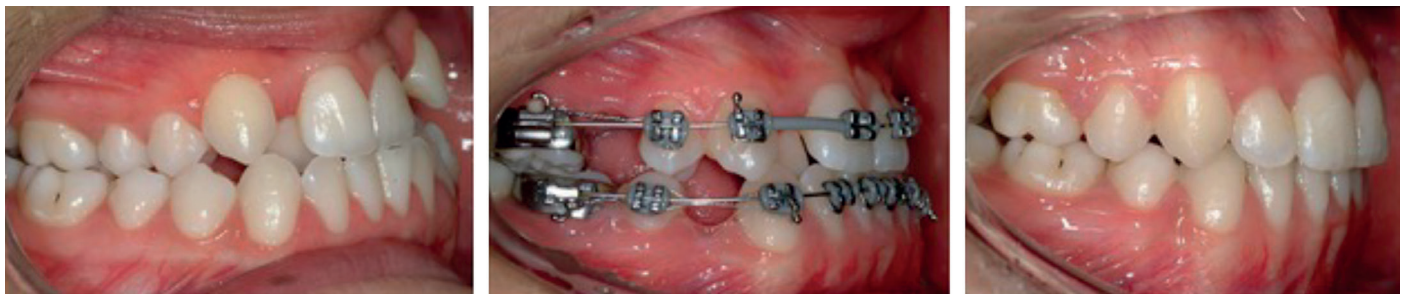

Figure 7. The Class III malocclusion was treated with OC, and the upper second and lower first premolars were extracted.

Figure 8. A patient who had previous arch alignment treatment with extraction of premolars. A Class III malocclusion was treated at the end of adolescent growth with extraction of the lower first premolars.

Figure 9. Class III malocclusion treated with extraction of lower first molars.

(Figure 9).[16,48] Alternatively, the buccal segment relationship can be corrected by retraction of the whole lower dentition, which has been made possible by the use of skeletal anchorage.

Patient expectations

While it may be successful in correcting the malocclusion, OC treatment will not change the underlying skeletal relationship or profile significantly. Therefore, it is important to ascertain the patient's concerns because this is crucial to deciding between OC or OGN surgery. If a patient is happy with their facial appearance,

Figure 10. (a,b) A patient with a Class III malocclusion who had no concerns regarding facial appearance and was treated with OC.

OC can be confidently undertaken (Figure 10). However, if the main concern is facial appearance and chin prominence, OGN surgery should be recommended (Figure 11).

OGN surgery for Class III malocclusions in non-growing patients is predictable and stable in the long term, especially in maxillary advancement and bimaxillary surgery.[49–53] OGN results in improvements in quality of life both physically and psychosocially after surgery, and is associated with high patient satisfaction rates.[49,50,54] Similarly, patients with a Class III malocclusion who receive OC treatment

Figure 11. (a,b) A patient with a Class III malocclusion whose primary concern was facial appearance, and who was treated with OGN.

also report high degrees of satisfaction.[17,55] In the small number of dissatisfied patients, this was a result of the residual mandibular prognathism. Therefore, if a presenting patient expresses concern about the relative prominence of their chin, this is an indication that OGN surgery may be the most appropriate treatment option.

Conclusions

The treatment of Class III malocclusions remains a challenge. Numerous studies have attempted to identify dental and skeletal parameters to assist in clinical decision-making, the commonest reported being the Wits and Holdaway analyses. However, no simple figure or equation has determined the best treatment in borderline cases. Other factors are equally as important, most notably the patients' concerns and expectations. Treatment decisions need to factor these in as part of a shared decision-making process.

Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.
Informed Consent: Informed consent was obtained from all individual participants included in the article.

References

1. British Standards Institute. *British Standard Glossary of Dental Terms BS4492*. London: BSI, 1983.
2. Hardy DK, Cubas YP, Orellana MF. Prevalence of Angle class III malocclusion: a systematic review and meta-analysis. *Open J Epidemiol* 2012; **2**; 75–82.
3. Lombardo G, Vena F, Negri P *et al*. Worldwide prevalence of malocclusion in the different stages of dentition: A systematic review and meta-analysis. *Eur J Paediatr Dent* 2020; **21**: 115–122. https://doi.org/10.23804/ejpd.2020.21.02.05
4. De Ridder L, Aleksieva A, Willems G *et al*. Prevalence of orthodontic malocclusions in healthy children and adolescents: a systematic review. *Int J Environ Res Public Health* 2022; **19**: 7446. https://doi.org/10.3390/ijerph19127446
5. Ellis E 3rd, McNamara JA Jr. Components of adult Class III malocclusion. *J Oral Maxillofac Surg* 1984; **42**: 295–305. https://doi.org/10.1016/0278-2391(84)90109-5
6. Guyer EC, Ellis EE 3rd, McNamara JA Jr, Behrents RG. Components of class III malocclusion in juveniles and adolescents. *Angle Orthod* 1986; **56**: 7–30.
7. Mackay F, Jones JA, Thompson R, Simpson W. Craniofacial form in class III cases. *Br J Orthod* 1992; **19**: 15–20. https://doi.org/10.1179/bjo.19.1.15
8. Ngan P, Hu AM, Fields HW Jr. Treatment of class III problems begins with differential diagnosis of anterior crossbites. *Pediatr Dent* 1997; **19**: 386–395.
9. Chen F, Terada K, Yang L, Saito I. Dental arch widths and mandibular-maxillary base widths in Class III malocclusions from ages 10 to 14. *Am J Orthod Dentofacial Orthop* 2008; **133**: 65–69. https://doi.org/10.1016/j.ajodo.2006.01.045
10. Reyes BC, Baccetti T, McNamara JA Jr. An estimate of craniofacial growth in class III malocclusion. *Angle Orthod* 2006; **76**: 577–584.
11. Kuc-Michalska M, Baccetti T. Duration of the pubertal peak in skeletal class I and class III subjects. *Angle Orthod* 2010; **80**: 54–57. https://doi.org/10.2319/020309-69.1
12. Mandall N, Cousley R, DiBiase A *et al*. Early class III protraction facemask treatment reduces the need for orthognathic surgery: a multi-centre, two-arm parallel randomized, controlled trial. *J Orthod* 2016; **43**: 164–175. https://doi.org/10.1080/14653125.2016.1201302
13. De Clerck H, Nguyen T, de Paula LK, Cevidanes L. Three-dimensional assessment of mandibular and glenoid fossa changes after bone-anchored class III intermaxillary traction. *Am J Orthod Dentofacial Orthop* 2012; **142**: 25–31. https://doi.org/10.1016/j.ajodo.2012.01.017
14. Mandall N, Aleid W, Cousley R *et al*. The effectiveness of bone anchored maxillary protraction (BAMP) in the management of class III skeletal malocclusion in children aged 11-14 years compared with an untreated control group: A multicentre two-arm parallel randomised controlled trial. *J Orthod* 2024; **51**: 228–239. https://doi.org/10.1177/14653125241255139
15. Voon KKR, Lim AAT, Wong HC *et al*. Decision-making patterns among expert and novice orthodontists and oral maxillofacial surgeons in the management of adults with Class III malocclusions and moderate degree of skeletal discrepancies. *J Orthod* 2023; **50**: 410–422. https://doi.org/10.1177/14653125231181603
16. Ning F, Duan Y. Camouflage treatment in adult skeletal Class III cases by extraction of two lower premolars. *Korean J Orthod* 2010; **40**: 349–357. https://doi.org/10.4041/kjod.2010.40.5.349
17. Alhammadi MS, Almashraqi AA, Khadhi AH *et al*. Orthodontic camouflage versus orthodontic-orthognathic surgical treatment in borderline class III malocclusion: a systematic review. *Clin Oral Investig* 2022; **26**: 6443–6455. https://doi.org/10.1007%2Fs00784-022-04685-6
18. Burns NR, Musich DR, Martin C *et al*. Class III camouflage treatment: what are the limits? *Am J Orthod Dentofacial Orthop* 2010; **137**: 9.e1–9.e13. https://doi.org/10.1016/j.ajodo.2009.05.017
19. Georgalis K, Woods MG. A study of class III treatment: orthodontic camouflage vs orthognathic surgery. *Aust Orthod J* 2015; **31**: 138–148.
20. Pinzan A, Castillo AAD, Janson G *et al*. Class III malocclusion camouflage treatment in adults: a systematic review. *J Dent* 2019; **1**: 4–12.
21. Alam MK, Nowrin SA, Shahid F *et al*. Orthognathic versus camouflage treatment of Class III malocclusion: a systematic review and meta-analysis. *Appl Sci* 2022; **12**: 3314. https://doi.org/10.3390/app12073314
22. Alhammadi MS, Almashraqi AA, Khadhi AH *et al*. Orthodontic camouflage versus orthodontic-orthognathic surgical treatment in borderline class III malocclusion: a systematic review. *Clin Oral Investig* 2022; **26**: 6443–6455. https://doi.org/10.1007/s00784-022-04685-6
23. Huang YP, Li WR. Correlation between objective and subjective evaluation of profile in bimaxillary protrusion patients after orthodontic treatment. *Angle Orthod* 2015; **85**: 690–698.
24. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. *Angle Orthod* 1996; **66**: 95–109.
25. Trauner R, Obwegeser H. The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. I. Surgical procedures to correct mandibular prognathism and reshaping of the chin. *Oral Surg Oral Med Oral Pathol* 1957; **10**: 677–689. https://doi.org/10.1016/s0030-4220(57)80063-2
26. Obwegeser HL. Surgical correction of small or retrodisplaced maxillae. The 'dish-face' deformity. *Plast Reconstr Surg* 1969; **43**: 351–365. https://doi.org/10.1097/00006534-196904000-00003
27. Troy BA, Shanker S, Fields HW *et al*. Comparison of incisor inclination in patients with Class III malocclusion treated with orthognathic surgery or orthodontic camouflage. *Am J Orthod Dentofacial Orthop* 2009; **135**: 146.e1–9.
28. Martinez P, Bellot-Arcís C, Llamas JM *et al*. Orthodontic camouflage versus orthognathic surgery for class III deformity: comparative cephalometric analysis. *Int J Oral Maxillofac Surg* 2017; **46**: 490–495. https://doi.org/10.1016/j.ijom.2016.12.001
29. Cassidy DW Jr, Herbosa EG, Rotskoff KS, Johnston LE Jr. A comparison of surgery and orthodontics in 'borderline' adults with class II, division 1 malocclusions. *Am J Orthod Dentofacial Orthop* 1993; **104**: 455-70. https://doi.org/10.1016/0889-5406(93)70072-v
30. Proffit WR, Fields HW, Larson B, Sarver DM. Combined surgical and orthodontic treatment. In: Proffit WR, Fields HW, Larson B, Sarver DM (eds). *Contemporary Orthodontics*. 5th edn. Elsevier, 2012.
31. Kerr WJ, Miller S, Dawber JE. Class III malocclusion: surgery or orthodontics? *Br J Orthod* 1992; **19**: 21–24. https://doi.org/10.1179/bjo.19.1.21
32. Stellzig-Eisenhauer A, Lux CJ, Schuster G. Treatment decision in adult patients with Class III malocclusion: orthodontic therapy or orthognathic surgery? *Am J Orthod Dentofacial Orthop* 2002; **122**: 27–37. https://doi.org/10.1067/mod.2002.123632
33. Rabie AB, Wong RW, Min GU. Treatment in borderline class III malocclusion: orthodontic camouflage (extraction) versus orthognathic surgery. *Open Dent J* 2008; **2**: 38–48. https://doi.org/10.2174/1874210600802010038
34. Benyahia H, Azaroual MF, Garcia C *et al*.

Treatment of skeletal class III malocclusions: orthognathic surgery or orthodontic camouflage? How to decide. *Int Orthod* 2011; **9**: 196–209. https://doi.org/10.1016/j.ortho.2011.03.005
35. Kochel J, Emmerich S, Meyer-Marcotty P, Stellzig-Eisenhauer A. New model for surgical and nonsurgical therapy in adults with Class III malocclusion. *Am J Orthod Dentofacial Orthop* 2011; **139**: e165-74. https://doi.org/10.1016/j.ajodo.2010.09.024
36. Tseng YC, Pan CY, Chou ST *et al*. Treatment of adult class III malocclusions with orthodontic therapy or orthognathic surgery: receiver operating characteristic analysis. *Am J Orthod Dentofacial Orthop* 2011; **139**: e485-93. https://doi.org/10.1016/j.ajodo.2010.12.014
37. Eslami S, Faber J, Fateh A *et al*. Treatment decision in adult patients with class III malocclusion: surgery versus orthodontics. *Prog Orthod* 2018; **19**: 28. https://doi.org/10.1186/s40510-018-0218-0
38. Ackerman JL, Proffit WR. Soft tissue limitations in orthodontics: treatment planning guidelines. *Angle Orthod* 1997; **67**: 327–336.
39. Lin J, Liaw J, Chang C, Roberts WE. *Orthodontics: Class III Correction*. Hsinchu City, Taiwan: Newton's A Co Ltd, 2012.
40. Holdaway RA. A soft-tissue cephalometric analysis and its use in orthodontic treatment planning. Part I. *Am J Orthod* 1983; **84**: 1–28. https://doi.org/10.1016/0002-9416(83)90144-6
41. Vasconcelos G, Kjellsen K, Preus H *et al*. Prevalence and severity of vestibular recession in mandibular incisors after orthodontic treatment. *Angle Orthod* 2012; **82**: 42–47.
42. Tepedino M, Franchi L, Fabbro O, Chimenti C. Post-orthodontic lower incisor inclination and gingival recession-a systematic review. *Prog Orthod* 2018; **19**: 17. https://doi.org/10.1186/s40510-018-0212-6
43. Steiner C. Cephalometrics in clinical practice. *Angle Orthod* 1956; **29**: 8–29.
44. Tweed CH. The diagnostic facial triangle in the control of treatment objectives. *Am J Orthod* 1969; **55**: 651–657. https://doi.org/10.1016/0002-9416(69)90041-4
45. Bennett JC, McLaughlin RP. *Fundamentals of Orthodontic Treatment Mechanics*. London: Le Grande Publishing, 2014.
46. Fastlight J. Tetragon: a visual cephalometric analysis. *J Clin Orthod* 2000; **34**: 353–360.
47. Arnett GW, Jelic JS, Kim J *et al*. Soft tissue cephalometric analysis: diagnosis and treatment planning of dentofacial deformity. *Am J Orthod Dentofacial Orthop* 1999; **116**: 239–253. https://doi.org/10.1016/s0889-5406(99)70234-9
48. Ruellas AC, Baratieri C, Roma MB *et al*. Angle class III malocclusion treated with mandibular first molar extractions. *Am J Orthod Dentofacial Orthop* 2012; **142**: 384–392.
49. Bailey LJ, Duong HL, Proffit WR. Surgical Class III treatment: long-term stability and patient perceptions of treatment outcome. *Int J Adult Orthodon Orthognath Surg* 1998; **13**: 35–44.
50. Busby BR, Bailey LJ, Proffit WR *et al*. Long-term stability of surgical class III treatment: a study of 5-year postsurgical results. *Int J Adult Orthodon Orthognath Surg* 2002; **17**: 159–170.
51. Proffit WR, Turvey TA, Phillips C. The hierarchy of stability and predictability in orthognathic surgery with rigid fixation: an update and extension. *Head Face Med* 2007; **3**: 21. https://doi.org/10.1186/1746-160x-3-21
52. Haas Junior OL, Guijarro-Martínez R, de Sousa Gil AP *et al*. Hierarchy of surgical stability in orthognathic surgery: overview of systematic reviews. *Int J Oral Maxillofac Surg* 2019; **48**: 1415–1433.
53. Rizk MZ, Torgersbråten N, Mohammed H *et al*. Stability of single-jaw vs two-jaw surgery following the correction of skeletal class III malocclusion: A systematic review and meta-analysis. *Orthod Craniofac Res* 2021; **24**: 314–327. https://doi.org/10.1111/ocr.12456
54. Zamboni R, de Moura FRR, Brew MC *et al*. Impacts of orthognathic surgery on patient satisfaction, overall quality of life, and oral health-related quality of life: a systematic literature review. *Int J Dent* 2019; **2019**: 2864216.
55. Uslu O, Akcam MO. Evaluation of long-term satisfaction with orthodontic treatment for skeletal class III individuals. *J Oral Sci* 2007; **49**: 31–39. https://doi.org/10.2334/josnusd.49.31