Combining a digital design-mediated surgery-first approach and clear aligners to treat a skeletal Class III defect for aesthetic purposes: a case report

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Abstract
This case report introduces digital surgery-first approach orthognathic surgery assisted by three-dimensional virtual planning and combined with invisible orthodontic treatment for a 21-year-old female patient with a skeletal Class III high-angle gummy smile malocclusion. We explored the clinical significance of the widespread application of digital technology for rapid development of the orthodontic/orthognathic field. The regional acceleratory phenomenon and clear aligners were used to achieve fast and aesthetic tooth movement after surgery. The treatment lasted only 8 months, and the patient was satisfied with the aesthetic results. The results remained stable after 1 year of follow-up. This case report highlights the advantages of combining a digital design and a surgery-first approach to produce accurate, rapid, safe, stable, and fulfilling cosmetic results. The combination of the surgery-first approach and clear aligners can facilitate patient-oriented surgical orthodontic treatment.

Keywords
Surgery-first approach, digital technology, regional acceleratory phenomenon, clear aligner, smile aesthetics, case report

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Introduction
The surgery-first approach (SFA), introduced in orthognathous surgery in recent years, has become popular among patients because of immediate improvements in the facial contour and shorter treatment times. Different from the traditional three-stage method, it can quickly correct the maxillo-mandibular position, providing a favorable environment for tooth movement.¹⁻³ Previous studies have shown the regional acceleratory phenomenon (RAP) effect of the SFA,⁴⁻⁵ explaining why this new surgical method can achieve safe, rapid, and stable movement. Clear aligners are gaining popularity over traditional fixed orthodontics in the orthodontic market because of their transparency and comfort; hence, many clear aligner products have become available.⁶⁻⁷ The present case report introduces a treatment innovation for a patient with a skeletal class III gummy smile that combines the SFA and clear aligners, with the total treatment being completed within 8 months. The treatment process was designed digitally, which improved the accuracy of the treatment plan and the precision of surgical execution, thus improving the overall treatment outcome. Digital techniques will eventually supplant traditional techniques altogether, improving the quality of oral rehabilitation, the economics of dental practice, and the patients’ perceptions.⁸

Case report
The reporting of this study conforms to the CARE guidelines.⁹

This paper describes our evaluation and treatment of a 21-year-old female patient with a gummy smile, maxillary and mandibular protrusion, and mandibular angle asymmetry (Figure 1). This study was reviewed and approved by the Medical
Ethics Committee of The Affiliated Hospital of Qingdao University (approval number: QYFYWZLL26977), and the patient provided verbal informed consent for publication of her information and images. The patient’s self-reported dental history was as follows. Five years previously, she had undergone fixed orthodontic treatment in another hospital for an open bite. Six months after the end of the treatment, her retainer was accidentally lost and she stopped maintenance treatment. Pretreatment facial evaluation at our hospital showed a hyperdivergent pattern of growth and asymmetrical mandibular angle, and intraoral photographs showed a gummy smile (Figure 1). Clinical examination revealed that both the maxillary and mandibular dental midlines were not coincident with the facial midline, instead deviating to the left. She had an overjet of 1.3 mm, an overbite of 0 mm, a Class I cuspid molar relationship on the right, a Class III cuspid relationship on the left, and a crossbite in the left premolar area. The patient also exhibited slight elongation in the lower third of the face and tension in the chin muscles when the lips were closed. A panoramic radiograph (Figure 2) showed that all teeth were present, including all four third molars. A lateral cephalometric radiograph analysis (Table 1) led to a diagnosis of skeletal Class III malocclusion ($\text{ANB} = 0.9^\circ$, $\text{Wits} = -4.9 \text{mm}$) with a hyperdivergent growth pattern (Frankfort-mandibular plane angle $= 31^\circ$).

The treatment objectives were to (1) improve the skeletal Class III malocclusion

![Figure 2. Pretreatment panoramic radiograph, lateral cephalometric radiograph, and cephalometric analysis.](image-url)
and gummy smile and correct the mandibular asymmetry, (2) establish a skeletal and dental Class I relationship, and (3) coordinate the transverse width of the maxillary and mandibular arches and release the individual tooth position crossbite in the posterior region.

Because the patient was diagnosed with skeletal Class III malocclusion with mandibular angle asymmetry and an obvious gummy smile, orthodontic/orthognathic combined treatment was the first choice. The patient also had the option of using implant anchorage-assisted camouflage orthodontic treatment. We explained the advantages and limitations of each approach in detail to the patient before treatment began. Because of the relatively orderly arrangement of her teeth and high requirements for aesthetics and time, she chose digital design-assisted SFA combined with postoperative invisible correction. She provided informed consent regarding this choice of surgical method.

We completed the preoperative digital surgery design (Figure 3) followed by the digital invisible orthodontics design (Figure 4). A cranial and maxillofacial computed tomography scan was performed before surgery, and the computed tomography data were imported into Mimics 20.0 software to establish the original digital model. Hard tissue markers were determined for three-dimensional (3D) reconstruction and measurement, analysis, diagnosis, surgical design, and guide plate fabrication. The operation was completed according to the digital surgical design and involved LeFort I osteotomy, bilateral sagittal split ramus osteotomy, and gonioplasty. During the orthognathic surgery, LeFort I osteotomy with impaction of 3 mm improved the gummy smile. The bone was moved 0.5 mm to the right to align the tooth midline with the facial midline, with the upper central incisor serving as the rotation center. Clockwise rotation of 2.0° in the sagittal plane, anticlockwise rotation of 0.5° in the coronal plane, and clockwise rotation of 0.5° in the horizontal plane were performed to harmonize the 3D symmetry. During mandibular bilateral sagittal split ramus osteotomy, according to the terminal occlusion position, the Pg point was used as the reference, and the bone was lifted 4.4 mm and moved 0.7 mm forward. Gonioplasty was performed to coordinate the symmetry of both

| Parameters         | Initial | Final | Retention 1 year | Normal ± SD |
|--------------------|--------|-------|------------------|-------------|
| SNA (°)            | 78.5   | 78.2  | 78.2             | 81 ± 0      |
| SNB (°)            | 77.6   | 75.6  | 75.8             | 80 ± 2      |
| ANB (°)            | 0.9    | 2.6   | 2.4              | 3 ± 2       |
| Wits (mm)          | −4.9   | −1.9  | −2.0             | −1 ± 0      |
| FMA (°)            | 31.0   | 33.5  | 33.6             | 25 ± 3      |
| Z-angle (°)        | 77.5   | 76    | 76.3             | 75 ± 5      |
| OP-FH (°)          | 9.6    | 10    | 9.8              | 10 ± 2      |
| Pog-Pog* (mm)      | 10.2   | 8.7   | 8.8              | 11.8 ± 1.8  |
| AFH (mm)           | 75.5   | 68.3  | 68.5             | 64 ± 0      |
| PFH (mm)           | 44.1   | 39.3  | 39.3             | 47 ± 0      |
| PFH/AFH (%)        | 58.3   | 57.5  | 57.4             | 70 ± 5      |

SD, standard deviation; FMA, Frankfort-mandibular plane angle; FH, Frankfort horizontal plane; MP, mandibular plane; AFH, anterior facial height; PFH, posterior facial height.
mandibular angles, and all four third molars were extracted. All procedures were performed by one surgeon. Intermaxillary fixation was performed for 14 days after surgery. Postoperative orthodontic procedures were initiated after the guide plate was removed and functional recovery was achieved, with a mouth-opening width of at least 40 mm and stabilization of occlusion. The time required for surgery was included in the total treatment time. Postoperative evaluation revealed improvements in the patient's facial shape with normalization of the overjet, overbite, and bilateral posterior sagittal relationship. These improvements were then reinforced using fine adjustment and alignment with a clear aligner (Figure 5), allowing us to align, level, and compensate for these changes. This facilitated coordination of the dental arch width and maxillary and mandibular occlusion. The invisible aligner was designed in 26 steps, and application of the RAP following surgery allowed the patient to change her aligners every 5 days, greatly reducing the total treatment time (the clear aligner lasted only 130 days). The orthodontic treatment was determined to be complete when a stable occlusion, proper alignment of the teeth, and appropriate overjet and overbite had been obtained. Some scholars have suggested that increased tooth movement after orthognathic surgery may be caused by increased activity and metabolic changes of osteoclasts in the alveolar bone caused by the surgery. The postoperative orthodontic treatment should be started no

Figure 3. Preoperative digital surgery design. (a) A 0.5-mm right shift was performed to align the midline of the tooth with the midline of the face. (a–c) With the upper central incisor as the center of rotation, the sagittal plane was rotated 2.0° obliquely, the coronal plane was counter-rotated by 0.5°, and the horizontal plane was counter-rotated by 0.5° to adjust the symmetry and (c) The bone was raised 3.0 mm to improve the gummy smile.
later than the second week after surgery so that the postoperative RAP can be used to shorten the treatment time.\textsuperscript{17}

The treatment (Figure 6) produced a more desirable occlusion with ideal overbite and overjet. It also facilitated a Class I bilateral cuspid molar relationship, improving the overall facial shape. Lateral imaging revealed a straightened face shape, reducing the elongation of the lower third of the face and reducing the appearance of the gummy smile. The patient’s improved smile and smile arc were coincident with her lower lip curvature. The patient exhibited bilateral mandibular angle symmetry and coordination. The treatment aims were accomplished, the patient’s chief complaints were addressed, and good occlusal and aesthetic results were achieved. The patient was satisfied with the treatment outcome.

The retention phase, initiated after completion of the orthodontic treatment, was not included in the treatment time. The total treatment lasted for 8 months, application of the maxilla bonded wire from 12 to 22 months (Figure 7(a), red arrow), and application of the mandible bonded wire from 33 to 43 months (Figure 7(a), blue arrow). Clear retainers were worn on both the maxilla and mandible at night only.

Good root parallelism was obtained via panoramic radiography, and no alveolar bone loss or root resorption was observed (Figure 7(a)).

Cephalometric analysis revealed significant changes (Figure 7(b), (c); Table 1). The ANB increased considerably from $0.9^\circ$ to $2.6^\circ$ and Wits from $-4.9$ to $-1.9$ mm; these changes were partly due to the clockwise rotation of the mandible.

\textbf{Figure 4.} Digital invisible design. (a) Initial ClinCheck images and (b) Final ClinCheck images.
(Figure 7(d)), which was necessary to correct the skeletal Class III malocclusion and posterior crossbite. The mandible underwent clockwise rotation, changing the mandibular plane (Frankfort-mandibular plane angle) from 31.0° to 33.5° (Figure 7(b)).

After 12 months of retention (end of treatment), both the occlusion and the facial shape remained well (Figure 8). Three-stage lateral cephalographic overlaps demonstrated stability after treatment for 1 year (Figure 9). One limitation of this case, however, is that the follow-up was not long enough to determine the long-term stability of the treatment effect. Further observation is needed to obtain these data.

**Discussion**

Traditionally, preoperative orthodontic treatment has been considered an important step to overcome postoperative occlusal instability and achieve a successful outcome of orthognathic surgery. The standard three-stage model has been widely used and has achieved good results. However, this technique still has shortcomings such as the long treatment cycle and aesthetic impact. Different studies have shown that the average preoperative orthodontic time ranges from 15.4 to 25.0 months and can even be as long as 47 months. During this process, the patient’s jaw malformation and occlusal disorder usually cannot be improved, and they become more serious after removal of the tooth compensation, which increases the patient’s psychological pressure. Preoperative orthodontics may also increase the patient’s chances of gingival regression, gingival hyperplasia, dental caries, root absorption, occlusal dysfunction, and chewing and
speech discomfort and may reduce his or her quality of life and compliance.\textsuperscript{13} With the higher pursuit of aesthetics and the continuous progress of orthognathic surgery, the SFA (i.e., orthognathic surgery before orthodontic treatment) has gradually shown advantages in improving the occlusion function and appearance at an early stage and shortening the treatment time,\textsuperscript{12} thus attracting increasingly more attention.

The SFA not only eliminates preoperative orthodontic treatment but also speeds up postoperative orthodontic treatment by utilizing the RAP, thus further reducing the total time of treatment. The RAP was first proposed by Frost\textsuperscript{14,15} in 1989 and states that the rate of remodeling of adjacent

\textbf{Figure 6.} Facial and intraoral photographs after another 8 months of treatment (completion).

\textbf{Figure 7.} Post-treatment panoramic and lateral cephalometric radiograph.
bone tissue increases after trauma or surgery. Liou et al.\textsuperscript{16} reported that the RAP is a complex physiological process, the main characteristics of which include accelerated bone remodeling activities and decreased bone mineral density in some regions. Studies have confirmed that the mobility of the upper and lower incisors and the serum level of C-terminal telopeptide of type I collagen are significantly increased from 1 week to 3 months after surgery and recover to the preoperative level in the fourth month after surgery. There is a significant correlation between the two changes. An increased concentration of C-terminal telopeptide of type I collagen indicates increased osteoclast activity and decreased bone mineral density. Therefore, the increased tooth movement after orthognathic surgery may be caused by increased activity and metabolic changes of osteoclasts in the alveolar bone caused by the surgery. Postoperative orthodontic treatment of patients should thus be started no later than the second week after surgery, allowing the postoperative RAP to shorten the treatment time.\textsuperscript{17}

Despite the obvious advantages of the SFA model, one difficulty is the need to overcome postoperative occlusal instability. This not only challenges the status quo but also constitutes a new model of cranio-maxillofacial surgery. There are two main ways to address this obstacle. First, Korean researchers seem to have taken advantage of the fact that surgery is performed in the same direction as postoperative orthodontic treatment.\textsuperscript{18} Second, Japanese researchers rely heavily on aggressive preoperative and postoperative tooth
management, including the use of cusp grinding and miniature screws, to compensate for surgical errors or skeletal relapse.\textsuperscript{19}

It should be noted that the SFA still has limitations and disadvantages. One is its unclear stability. Comparison of the therapeutic effect and stability between the SFA and traditional treatment is still controversial in the academic circle, but it is generally believed that the therapeutic effect and stability are not significantly different between the two. Seifi et al.\textsuperscript{20} reported that there was no significant difference between the two treatment modes in the stability of the jaw and teeth after treatment for patients with Class III malocclusion. Jeong et al.\textsuperscript{21,22} compared the long-term anteroposterior and vertical stability of the mandible in patients with Class III malocclusion undergoing the SFA or traditional treatment mode and found no significant difference. Several reviews have described the therapeutic effect and stability of the SFA in patients with skeletal Class III malocclusion.

Huang et al.\textsuperscript{23} reported that the SFA could achieve the same or better long-term treatment effect compared with

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure9.png}
\caption{Superimposition of cephalometric tracings. black, pretreatment; red, post-treatment; blue, 1-year follow-up.}
\end{figure}
the “orthodontic-orthognathic-orthodontic”
treatment model for patients with skeletal
Class III malocclusion, including trans-
verse, vertical, and sagittal stability of the
jaw and teeth. Peiro-Guijarro et al.4 found
that the SFA is a stable and predictable
treatment for patients with skeletal Class
III malocclusion but that its stability is
not as good as that of traditional treatment.
It should be emphasized that analysis of the
treatment efficacy and stability is suscepti-
ble to a variety of confounding factors, such
as differences in indications, surgical proce-
dures,22 and orthodontic and orthognathic
surgeons’ skill levels. Because of the large
clinical heterogeneity of the literature to
date, a meta-analysis cannot be conducted,
and the level of evidence provided is very
limited. Moreover, most existing reports
describe retrospective studies; thus, pro-
spective studies with a sufficient sample
size are still needed to provide more precise
evidence for evaluation of the therapeutic
effect and stability. Another limitation in
terms of the indications for the SFA is
that this technique is not suitable for
patients with crowded dentition, steep
curve of Spee, or large inclination of the
upper incisors; for this group of patients,
preoperative orthodontic compensation is
still required.23

Traditional orthognathic surgical design
is based on two-dimensional X-ray
images,24 such as cephalometric tracings
and plaster casts. There are inevitably devi-
ations in the steps of dental cast making,
face bow transferring, and model surgery;
it is difficult to predict exactly what move-
ment is required, and prediction of the post-
operative facial appearance is not intuitive
enough. However, patients undergoing orthognathic surgery often have higher aes-
thetic and functional requirements than
patients undergoing other types of surgery,
and planning requires a high degree of
accuracy, meaning that even small devia-
tions can result in suboptimal results.

Digital orthognathic planning can obtain
more accurate cranio-maxillofacial features
of patients through 3D reconstruction and
matching of the patients’ craniomaxillofa-
cial CT, 3D photography, dentition model
scanning, and other digital imaging data to
achieve more accurate measurement, diag-
osis, virtual design, guide plate creation,
and postoperative effect evaluation.25 The
virtual surgical plan can determine the opti-
mal position of the osteotomy line and rigid
fixation with the help of a surgical
guide.26,27 Using 3D virtual orthodontic
simulation, orthodontists can accurately
predict the tooth movement required for
the final occlusion.17 All of these techniques
improve the accuracy of the treatment plan
and the precision of surgical execution, thus
improving the overall treatment out-
come.26,28 Given the continuing develop-
ment of related software, the future of
digital design will become simpler and
more accurate and facilitate better surgical
and aesthetic outcomes for these patients.

The invisible aligner system is a new type
of orthodontic treatment technology that
was first introduced in the United States
in the late 1990s. It uses image processing
and computer-aided design and fabrication
technology with rapid prototyping technol-
yogy to assist in orthodontic treatment.29
This technology enables the design of
tooth movement by 3D visualization and
involves the processing and fabrication of
a series of transparent, non-bracket, elastic
plastic aligners that control the magnitude
and direction of orthodontic forces, thus
achieving the goal of realistic, visualized
orthodontic treatment.29 Compared with
traditional fixed orthodontic devices, invis-
ible orthodontic devices have the character-
istics of beauty, comfort, and convenience
for the patient. In recent years, clear align-
ers have been widely used in clinical prac-
tice and are favored by the majority of
patients; thus, they are gradually occupying
a larger place in the field of orthodontics.
The clear aligner needs to be worn for >22 hours per day to achieve a satisfactory orthodontic effect, and treatment compliance is high.\textsuperscript{30} Invisible orthodontic technology can also be used to predict the results of orthodontic treatment by digital 3D reconstruction, allowing the patients to directly watch the a dynamic simulation video of the process and results of their orthodontic treatment; this is convenient for doctor–patient communication. After design and machining, the orthodontic teeth can be moved to the final position, avoiding the round-trip tooth movement during fixed orthodontic treatment and reducing the risk of root absorption.\textsuperscript{31} In addition, the time interval between return visits in patients with clear aligners is longer, which can effectively decrease the treatment time and improve the effect.\textsuperscript{29} Thus, clear aligners are of great significance in the development of orthodontic technology and are worthy of widespread clinical application.

With the recent remarkable improvements in people’s material and spiritual lives, the demand for beauty is constantly increasing. Facial attractiveness plays a crucial role in social interactions.\textsuperscript{32} Therefore, it is not surprising that an increasing number of people are seeking orthodontic treatment to improve the aesthetics of their smile. A “gummy smile” is defined as exposure of more than 3.0 mm of gingival tissue during a forced smile.\textsuperscript{33} This not only negatively affects smile aesthetics but can even influence self-esteem and social relationships.\textsuperscript{32} In the present case, one of the patient’s chief complaints was a gummy smile. Her initial smile was obviously gummy with a larger buccal gallery area on both sides, resulting in a less full smile; she also had a too-straight dental arch, unattractive smile arc, and several other aesthetic problems. However, we were able to combine digital design, surgical adjustment of the jaw position, and postoperative fine adjustment to improve the aesthetic attractiveness of the patient’s smile, and her smile was filled out to produce a more youthful look. The components of a smile also influence each other, making it necessary for orthodontists to understand the complex relationship between these components to achieve ideal smile aesthetics following orthodontic treatment and achieve overall facial harmony.\textsuperscript{33,34}

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