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Early changes in condylar position after mandibular advancement: a three-dimensional analysis

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Abstract. The aim of this study was to perform a three-dimensional (3D) assessment of positional changes of the mandibular condyle after bilateral sagittal split osteotomy (BSSO). A prospective evaluation of 22 skeletal class II patients who underwent a BSSO for mandibular advancement was performed. Pre- and postoperative cone beam computed tomography scans were taken. Using the cranial base as a stable reference, the pre- and postoperative 3D skull models were superimposed virtually. Positional changes of the condyles were assessed with a 3D colour mapping system (SimPlant O&O). A Brunner–Langer statistical test was applied to test the null hypothesis that the condylar position remains stable after BSSO. The level of significance was set at 0.05. The mean mandibular advancement in the studied sample was 6.7 ± 1.6 mm. Overall, the condylar positional changes after BSSO for mandibular advancement were statistically significant ($P < 0.05$). A positive correlation was found between the displacement of the left condyle and the amount of mandibular advancement ($P < 0.01$). The results of this study suggest that statistically significant changes of condylar position occur after mandibular advancement. Long-term evaluation is needed to assess the capacity of the temporomandibular joint to adapt to these changes.

Key words: temporomandibular joint; bilateral sagittal split osteotomy; retrognathia; three-dimensional analysis.

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Significant skeletal dysplasia in non-growing patients is efficiently managed with orthognathic surgery and orthodontics. In the particular case of mandibular hypoplasia, the bilateral sagittal split osteotomy (BSSO) is the most common surgical technique for mandibular advancement.[1–7]

A higher prevalence of temporomandibular joint disorders (TMD) has been identified in patients with underlying malocclusion,[8] especially in the context of mandibular hypoplasia and Angle class II malocclusion. While orthognathic surgery will correct a skeletal base discrepancy, there is ongoing concern about its potential beneficial/deleterious effects on the temporomandibular joint (TMJ).

Although many studies have reported an improvement in TMD symptoms after orthognathic surgery,[4,7–10] others have detected postoperative worsening of these symptoms.[5,11] In a systematic review on the influence of orthognathic surgery on TMD, Abrahamsson et al. concluded that there is insufficient scientific evidence to assess TMD before and after surgery and that well-designed studies are needed in this regard.[11]

In this context, the investigation of possible changes in condylar position and in the disc–condyle relationship after orthognathic surgery is particularly relevant. There is currently no consensus in relation to this. Several study groups have claimed that no statistically significant changes in condylar position occur after surgery.[4,6,7,10,12–14] Conversely, Bailey et al. detected condylar position changes after surgery in 5–10% of the patients who underwent surgical advancement of the mandible.[15] The percentage of observable TMJ changes after BSSO was substantially higher in the study by Saka et al., especially when a splint was not used (54%).[16] It has been suggested that if these changes are small enough, they could allow adaptive remodelling without any TMJ damage.[7,17] It seems that physiological adaptation may fit small changes in condylar position, but that this process requires a long time.[7]

At any rate, if positional changes do occur, their significance is poorly understood. Positional modifications could promote relapse, TMJ problems, or condylar resorption.[3–8,10,11,13–22] Regarding the latter, Arnett et al. showed that posteriorization and medial or lateral torquing during orthognathic surgery could cause morphological changes and lead to progressive condylar resoption.[18,19] In order to minimize this possible movement of the condyles, some authors have advocated the use of different condylar positioning devices during surgery.[2,3] However, these devices have not been proven to improve condylar positioning when compared to a control group.[2,3] Consequently, there is currently no scientific evidence to support their use in orthognathic surgery.

The introduction of cone beam computed tomography (CBCT) imaging has provided an accurate tool to evaluate condylar position.[7,14,17,23] X-ray films have important limitations in terms of precision and the assessment of mediolateral movements. Conversely, CBCT enables a comprehensive three-dimensional (3D) evaluation of the TMJ, provides highly accurate linear measurements,[17] and permits superimposition of pre- and postoperative situations.[20]

The aim of the present study was to apply CBCT technology to evaluate postoperative changes in the TMJ condyle after BSSO for mandibular advancement. In addition, the potential effect of several patient-related and process-related variables on condylar displacement was assessed.

Patients and methods

A prospective radiological evaluation of 22 consecutive patients who underwent BSSO for mandibular advancement at a maxillofacial surgery institute in Barcelona, Spain was performed. The usual imaging protocol for orthognathic surgery cases was followed: CBCT scans were taken pre- and postoperatively (15 days after surgery). This study followed the Declaration of Helsinki on medical protocol and ethics and was approved by the necessary ethics committees.

Patients were selected on the basis of the following inclusion criteria: age ≥18 years, skeletal class II profile in need of surgical correction, no history of TMD, and signed informed consent. Exclusion criteria were skeletal dysplasia requiring additional surgical procedures (i.e., maxillary Le Fort I osteotomy, surgically assisted rapid palatal expansion, etc.), asymmetry, congenital anomalies, history of trauma, and absence of or disagreement with informed consent.

For each patient, the following variables were recorded: age at the time of surgery, sex, amount of mandibular advancement (mm), and type of occlusal plane rotation (clockwise vs. counter-clockwise).

All patients were operated on under general anaesthesia and controlled hypotension. The mandibular advancement procedure was performed according to the standardized BSSO technique defined by Trauner and Obwegeser[24] and incorporating the modifications of Hunsuck[25] and Dal Pont.[26] The proximal (condyle-bearing) fragments were repositioned into the uppermost-anterior part of the fossa with a bidirectional manoeuvre. One single straight miniplate with two screws on each side was used to achieve fixation of the fragments. Patients left the operating room without any rigid intermaxillary fixation apart from two guiding elastics. At 15 days postoperative, a clinical examination of the TMJ was performed. At this time point, patients initiated active physiotherapy and were instructed to do maximum mouth opening exercises with the aim of gaining normal joint function.

CBCT scans were taken with an i-CAT Vision device (Imaging Sciences International, Hatfield, PA, USA). Standard scanning conditions for orthognathic surgery patients were ensured: patient breathing quietly, sitting upright, with the clinical Frankfort horizontal plane parallel to the floor, and biting on a wax-bite in centric occlusion. Preliminary data were saved in DICOM format. For image processing, a computer with the following characteristics was used: Pentium 4 Processor, 3.8 GHz, W/SP5 Windows XP Professional, 120 GB of memory, 2 GB of RAM, and a screen of 20 inches minimum. i-CAT Vision (version 1.8.0.5; Imaging Sciences International) and SimPlant O&O (Materialise Dental SL) software programs were installed on this computer for image viewing and processing, respectively.

A 3D simulation of the pre- and postoperative anatomy was performed. An appropriate mask and region of interest were defined for this purpose. Through automatic segmentation, a preview image was obtained. This was later optimized by manual segmentation, eliminating possible artefacts.

Once the 3D reconstructions of the pre- and postoperative conditions had been obtained, they were superimposed virtually in order to evaluate possible changes in condylar position in all three planes of space. Superimpositions were done using the cranial base as a stable anatomical reference, since it is assumed to remain unchanged after surgery. The software allowed for proper adjustment of the superimposed images in the three views (sagittal, coronal, and axial) in every single slice (Fig. 1). Once the correct superimposition had been obtained, the relationship was saved as the 'home position', such that the program would always connect the two 3D reconstructions in the same relationship. Following this methodology, the program created a coded overlay colour map that enabled visual analysis and objective quantification of the changes in three dimensions (Fig. 2).

The 3D analysis of condylar position was systematized as follows: five points were defined on each condyle; these points were named anterior, posterior, superior, medial, and lateral (Fig. 3).

Positional changes were evaluated separately for each point. Because each colour indicates an interval of change in the colour map, it was decided that the highest value of each corresponding interval would be recorded. This methodology assumed that the value '0' is not possible and ensured that the highest possible change – in other words, the 'worst possible situation' – was assumed systematically for each point.

The data analysis was performed using SPSS for Windows version 15.0.1 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used for the quantitative analysis. Following a Shapiro–Wilk test in which a normal distribution was ruled out, a non-parametric Brunner–Langer test was performed to test the null hypothesis that the condylar position remains stable after BSSO for mandibular advancement. Spearman's correlation coefficient was used to test the correlation between the changes in condylar position and the amount of advancement, age, and sex, and also between contralateral condyles. The level of significance was set at 0.05.

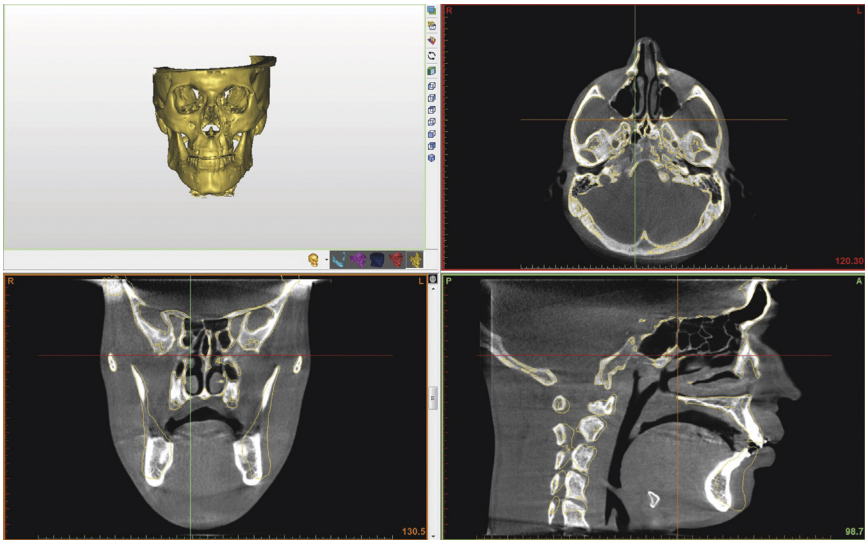

Fig. 1. Superimposition of the pre- and postoperative conditions. The cranial base was used as a stable reference area to superimpose the two images and was adjusted in the sagittal, coronal, and axial planes.

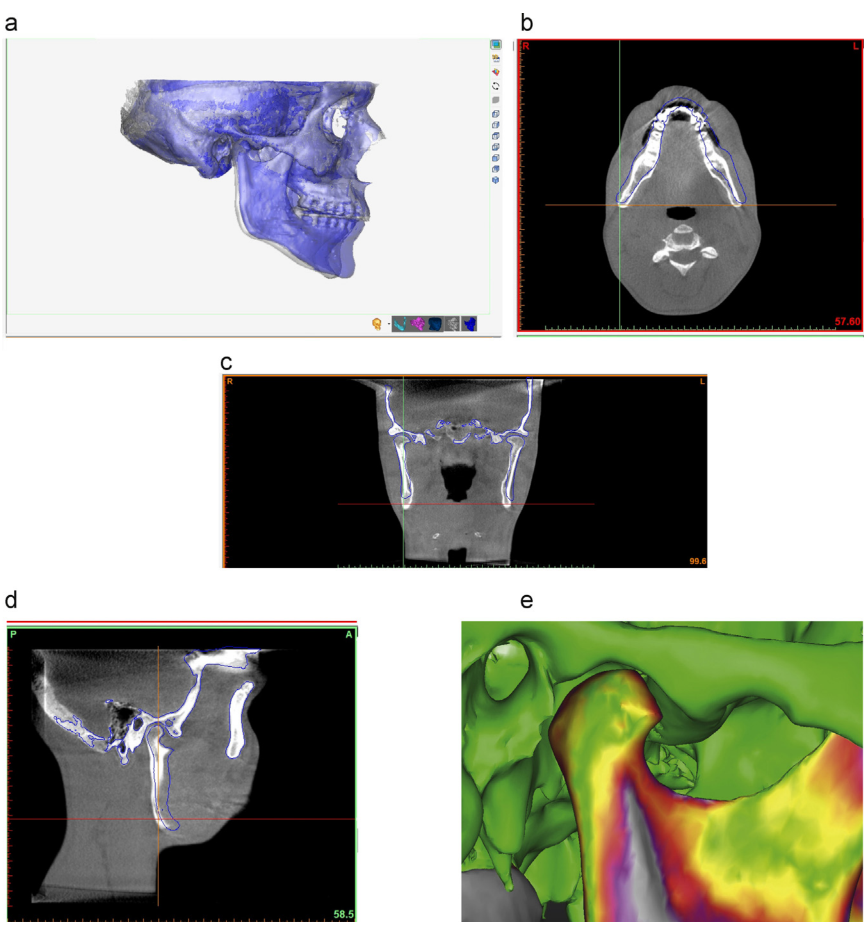

Fig. 2. Preoperative (grey) and postoperative (blue) superimposition. (A) 3D superimposition. (B) Mandibular advancement in axial view. (C) Mandibular condyle and mandibular ramus position in coronal view. (D) Mandibular counter-clockwise rotation in sagittal view. (E) Coded overlay colour map of the pre- and postoperative conditions. Green areas denote no change (0–0.5 mm), whereas yellow (0.5–1 mm), orange (1–1.5 mm), red (1.5–2 mm), and purple (2–2.5 mm) areas denote changes between the two situations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Results

The study sample ($N = 22$) comprised 14 women (63.6%) and eight men (36.4%); their mean age at the time of surgery was 34.3 years (range 19–59 years). The mean mandibular advancement was 6.7 ± 1.6 mm. A clockwise rotation was performed in 59.1% of the patients ($n = 13$) and a counter-clockwise rotation in 40.9% ($n = 9$).

Table 1 displays the mean positional changes that occurred for both condyles. The overall displacement reached statistical significance ($P < 0.05$).

The descriptive analysis revealed that the greatest positional changes occurred in the posterior point, where displacement was greater than 1 mm in the right condyle for 36% of patients and in the left condyle for 32% of patients. The second greatest displacement corresponded to the lateral point. For the remaining studied points, only 15–20% of the patients showed displacements beyond 1 mm. Nevertheless, this difference was not statistically significant between measured points or between contralateral condyles.

Spearman's correlation coefficient confirmed a positive correlation in the posterior and lateral points between the two condyles that turned out to be statistically significant ($P < 0.05$ and $P < 0.01$, respectively). However, the concordance was low for the posterior point (kappa index, $I_\kappa = 0.277$) and moderate for the lateral point ($I_\kappa = 0.489$).

Demographic variables (age and sex) showed no statistically significant influence on changes in condylar position. Conversely, occlusal plane rotation and the amount of mandibular advancement did show a statistically significant correlation with changes in condylar position.

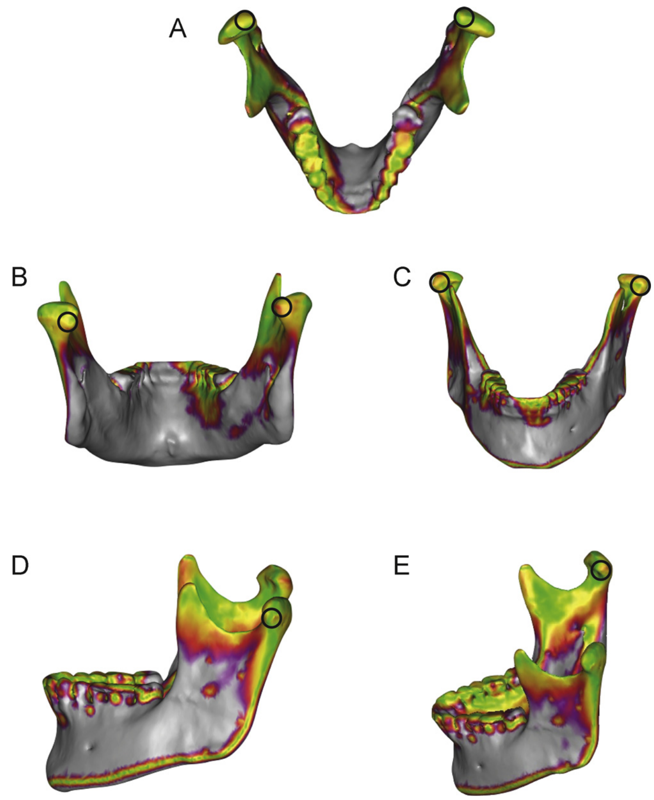

Fig. 3. Regions of interest taken to systematize the condylar position. For each point, the highest value of the colour interval was recorded. (A) Superior point: the most superior point from a craniocaudal view. (B) Posterior point: the most posterior point from the posterior view of the 3D reconstruction. (C) Anterior point: the most anterior point from the anterior view of the 3D reconstruction. (D) Lateral point: the most external point from the lateral view. (E) Medial point: the most external point from the medial view.

In particular, a direct positive correlation was found between condylar displacement and the amount of mandibular advancement. Interestingly, this relationship was statistically significant for the left condyle ($P < 0.01$) but not for the right condyle ($P = 0.053$) (Table 2). Finally, a statistically significant association between the type of occlusal plane change and the movement of the condyles was found. When a clockwise rotation of the maxillomandibular complex was performed, condylar displacement was greater in the right condyle ($P < 0.05$). Conversely, when a counter-clockwise rotation was done, the left condyle showed greater displacement ($P < 0.05$).

Postoperatively, all patients were symptom-free in terms of TMJ pathology and no pathological changes were visible in the CBCT scan.

Table 1. Changes in the different points on the left condyle and right condyle; mean and standard deviation values (SD).[a]

	Number	Mean	SD	Median
Left condyle				
Superior	22	1.07	0.62	1.00
Anterior	22	0.95	0.46	1.00
Posterior	22	1.02	0.63	0.75
Medial	22	0.84	0.61	0.50
Lateral	22	0.95	0.57	1.00
Right condyle				
Superior	22	0.86	0.49	0.50
Anterior	22	0.91	0.53	0.75
Posterior	22	1.09	0.65	1.00
Medial	22	0.77	0.43	0.50
Lateral	22	1.16	0.61	1.00

[a] Data are expressed in millimetres.

Table 2. Descriptive analysis of the amount of mandibular advancement.[a]

	Amount of mandibular advancement		
	Total	<6 mm	>6 mm
Right condyle			
Number	22	9	13
Mean	0.96	0.89	1.01
SD	0.24	0.24	0.24
Minimum	0.60	0.60	0.70
Maximum	1.40	1.30	1.40
Median	1.00	0.90	1.00
Left condyle			
Number	22	9	13
Mean	0.97	0.82	1.06
SD	0.36	0.26	0.40
Minimum	0.50	0.50	0.50
Maximum	1.98	1.30	1.98
Median	0.90	0.70	1.00

SD, standard deviation.
[a] Data are expressed in millimetres.Mean changes in the right and left condyles related to the amount of mandibular advancement.

Discussion

The potential connection between orthognathic surgery and secondary TMJ changes continues to be a topic of debate for maxillofacial surgeons and orthodontists. Whereas postoperative improvements in TMJ symptoms[4,8–10] and better mandibular dynamics[2,8,9] have been reported by some study groups, it has also been suggested that positional modifications of the condyle–fossa relationship can promote postoperative occlusal instability and relapse,[3,21] TMD,[5,16] or progressive condylar resorption.[18,19]

Although some study groups have not found any statistically significant changes in condylar position after orthognathic surgery,[10,13,14,23] it must be pointed out that these evaluations were often based on two-dimensional imaging methods such as lateral cephalograms,[10] where condylar changes cannot be assessed three-dimensionally. In this context, several researchers have stated the need to apply CBCT technology and 3D superimposition techniques in future investigations.[7,14,15,17,23,27]

The present study is an example of such a recommended methodology. Primary CBCT data were processed in order to perform a virtual superimposition of the 3D reconstructions of the pre- and immediate postoperative (15 days postoperative) condylar situations. Although the whole process is technically demanding and quite time-consuming (120 min are needed for the complete evaluation of one single case), it is believed that this methodology enables a detailed analysis of positional changes of the TMJ.

Globally, statistically significant changes in condylar position were found after BSSO for mandibular advancement ($P < 0.01$). These findings are in agreement with those of other studies.[22,28] In the present sample, the posterior and lateral aspects of the condyle tended to vary more than the other points evaluated. Using 3D superimposition, Carvalho et al. found that the posterior condylar region was the area that exhibited the greatest changes with remodelling at the 1-year follow-up.[27]

From the methodological point of view, it is important to point out that due to the system's inability to distinguish between 0 and 0.5 mm in the green range of the colour map, it was assumed that the 0 value (in other words, no positional change) is not possible. The maximum possible error (the highest value of the numerical range and thus the greatest possible change in condylar position) was considered systematically. Nevertheless, the overall changes were below 1 mm in 75% of patients. This finding is also in agreement with the results presented by Carvalho et al., who reported that the mean change in condylar position was smaller than 1 mm (left, 0.98 ± 1.46 mm; right, 0.81 ± 1.40 mm); only four patients showed changes above 2 mm.[27] Interestingly, although their sample was clinically symmetrical, displacement was usually unilateral. These results differ from those of the present study, in which a positive correlation between the displacements of both condyles could be established. Chen et al. did not find any significant differences between the right and left condylar changes either.[22]

At any rate, long-term prospective studies are necessary to ascertain whether postoperative condylar displacement is permanent or not. With a long-term follow-up period of 18.36 ± 4.01 months, Kim et al. demonstrated that the condyle moved slightly backwards to its preoperative position,[7] suggesting that the TMJ can adapt to small positional changes over time.[7,17,21] Early postoperative conditions such as intra-articular oedema or stretching of the masticatory muscles and temporomandibular ligaments may explain short-term positional changes,[22] which might recover over time. Another factor capable of playing a role in early condylar displacement may be the presence of a bony interference in the osteotomy gap. This has been related to mediolateral torquing of the condyles,[22,29] which is probably the most harmful type of condylar displacement due to its potential for disc compression and the subsequent risk of condylar resorption.[3,18,19] Conversely, small positional changes may lead to physiological remodelling and joint adaptation without secondary TMJ damage.[7] Indeed, based on a 3D superimposition methodology, Carvalho et al. reported visible morphological changes and remodelling of the posterior aspect of the condyle at 1 year after BSSO, but no resulting TMD symptomatology.[27]

Another important aspect that requires further clarification is the potential relationship between postoperative condylar displacement and surgical relapse. In this regard, Gerressen et al. suggested that intraoperative distraction of the condyle from the fossa was related to early relapse.[3] Conversely, in their study comparing a group with stable postoperative results and a group with relapse, Zafar et al. did not find any statistically significant changes in condylar displacement.[30] They concluded that small positional changes of the condyle were not related to skeletal relapse.

In addition to the evaluation of the occurrence of condylar changes after mandibular advancement, a second aim of the present investigation was to assess the potential influence of several factors on condylar position. Patient-related variables such as age and sex did not show any statistically significant influence on postsurgical changes. However, other factors did show a relevant association. First, the amount of mandibular advancement was found to be positively correlated with the amount of condylar displacement on the left side ($P < 0.01$). The influence of this factor has been reported previously by Harris et al., who demonstrated that the amount of mandibular advancement was correlated with condylar angulation and supero-inferior changes in condylar position.[28] Second, this study also found a statistically significant association between occlusal plane changes and condylar displacement. Interestingly, the type of rotation influenced the pattern of postoperative change. When a clockwise rotation was introduced, greater changes occurred in the right condyle; by contrast, when a counter-clockwise rotation was performed, the greater change happened in the left condyle. There appears to be no other reference to such a preliminary finding in the scientific literature. Although this requires further investigation, the surgeon's position during surgery could play a role (in the setting of the study institution, the operator stands on the right of the surgical table). Most studies evaluating the influence of maxillomandibular complex rotation on the TMJ have focused on joint symptomatology. Frey et al. reported that large mandibular advancements (>7 mm) with counter-clockwise rotation were related to greater muscle tenderness and joint symptoms.[5] Nevertheless, these symptoms tended to decline over time and thus might be clinically significant only in the short term.[5]

In conclusion, the results of this study suggest that statistically significant displacement of the condyles occurs after BSSO for mandibular advancement. This displacement shows a positive correlation with the magnitude of advancement, and the region of greatest change tends to be located in the posterior aspect of the condyle. These findings apply to the immediate postoperative situation and require further corroboration in the long term. Similarly, the capacity of the TMJ to adapt to these positional changes and the possible influence of these displacements on skeletal relapse are relevant issues that must be evaluated in future studies.

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Competing interests

The authors declare no conflicts of interest.

Ethical approval

This study was approved by the Ethics Committee of the Teknon Medical Centre and the Ethics Committee of the Universitat Internacional de Catalunya.

Patient consent

Not required.

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