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A STUDY ON ACCURACY OF MAXILLARY REPOSITIONING BY EXTERNAL MEASURING TECHIQUE

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Abstract

Internal measurement technique has been commonly and classically used to guide down-fractured maxilla by Le Fort I osteotomy into its new position during intraoperative procedure for correlating preoperative model works with surgery. However, It has been challenged now by several authors due to some problems as its inaccuracy in three-dimensional changes at surgery, difficulty to measure during surgery and impossibility of rechecking at the end of surgery etc.

The purpose of this study was to evaluate the accuracy of maxillary movement by external measuring technique and to determine its accuracy between the prediction tracing and a new maxillary position.

The results indicate that the external measuring technique was predictable in the vertical, horizontal and transverse change of the maxilla as its prediction, however, it has a tendency to shift the maxilla more anterior and inferior in overall direction than prediction.

Post-operative canting difference were mimic, however Ehange of the maxillary dental midline was large and had a right-shifting tendency.1 The precise methods to keep maxillary dental midline as same as prediction and the avoidance of uneven force applied to the mandible for autorotation should be necessary during surgery in use of external measurement technique.

I. INTRODUCTION

The simultaneous two jaw surgery is now popularized in the most of orthognathic surgeons because not only it can establish three-dimensional correction of Dentofacial deformities more easier in one stage, but also establish more reliable ideal occlusal relationship and harmonized face in same time. In this surgical procedures, accurate repositioning of down-fractured maxillary segments is the most important because it will act lately as a key in concomitant repositioning of mandible. Therefore, it is very important to use a reliable method which can obtain and maintain a correct position of newly positioned maxillary segment during surgery as same as prediction.

Classically, the internal measuring technique (IMT) by using of tentative landmarks or points(internal reference point : IRP) marked by burs on the anterior wall of maxilla have been used references for moving down-fractured segments of the maxilla during surgery, however several surgeons have been proposed recently several problems of an efficacy of IMT[2,3,5,6]. They described that IMT may not precise to transfer predicted measurements because internal measuring of IRP is two-dimensional measures and is ususally not coincide real changes of moving segments in three-dimension. Furthermore, IRP may become obliterated by unexpected reduction or loss of the lateral maxillary wall, or may be obscured by over lapping of segments when telescoping of segments is severe. And it is not possible to recheck

the measurements once the soft tissue wounds were closed[2,3,6]. To solve these inefficacies, the external measuring technique(EMT) using external reference points(ERP) has been proposed by several authors recently. This technique use a vertical dimension between both reference points on frontonasal area and maxillary incisor as a practical measurement and an intermediate splint which it was established by model surgery performed on a semi-adjustable articulator, between movable segments of the maxilla and the unoperated mandible[3,6].

Because the measuring points are made externally, it is possible to obtain a precise measuring and calcualtion during surgery and even after the soft-tissue wounds are closed and has been also prefered for the reason of convenience. After Johnson[3] introduced EMT at first in 1985 using a suture on the frontonasal skin, an excellent experiment was conducted by Van Sickels et al.[6] in 1986 to compare the errors made by both IMT and EMT of 11 subjects in each group. As a result, they described that the EMT had significantly less errors in both horizontal and vertical changes between the predicted and actual new maxillary position.

The purpose of this study was to evaluate and determine the efficacy of EMT in actual movement of maxillary segments in our operation and to confirm the usefulness of ERP afteruse. We evaluated predictability in both horizontal and vertical changes of the maxilla on lateral cephalograms and predictability of canting correction and midline changes on postero-anterior cephalograms.

II. MATERIAL AND METHODS

Seventeen patients, 8 males and 9 females, who underwent simultaneous surgery of maxilla and mandible performed by one surgeon were investigated and cleft palate patients were excluded especially in this investigation. The main surgical change of the maxilla was posterior impaction and others were advancement, canting correction, down-grafting, anterior and posterior impaction, and combination of above procedures as in Table-1.

All of the maxillary segments were osteotomized by means of modified Le Fort I technique and repositioned depend on EMT. Before osteotomy of the maxilla, a 0.02-inch Kirshner's wire was inserted into the bone around the frontonasal suture area as a top reference point and distance from it to the lowest margin of orthodontic bracket attached on the right maxillary central incisor(a bottom reference point) was measured on caliper as showed in Figure-1.

Figure 1. A picture of external measuring during operation

To get a precise three-dimensional movement of the osteotomized maxilla in its predicted position, an intermediate acrylic splint which made from the predicted model surgery work on the semi-adjustable articulator was applied between osteotomized maxilla and the unoperated mandible, and then moved it by means of autorotation of the mandible until the external measure was coincided to the predicted measure. All of the repositioned maxillary segments was fixed rigidly to the cranial part of the maxilla using mini-plate and screws.

III. METHODS OF ANALYSIS

(1) Lateral Cephalograms

To evaluate dimensioanl errors between predicted and post operative position of the maxilla, all cranial structures, maxillary central incisor maxillary first

molar and palatal outlines of the pre-and post-operative lateral cephalograms were traced on 0.003-inch acetate sheets with a 0.3㎜ lead pencil by one investigator. And then both pre-and post-operative tracings were superimposed each other by means of cranial base superimposition. Two reference lines and four special reference points were established on the superimposed tracings; reference landmarks, planes, and measurements used in this study are illustrated in Figure-2. as follows:

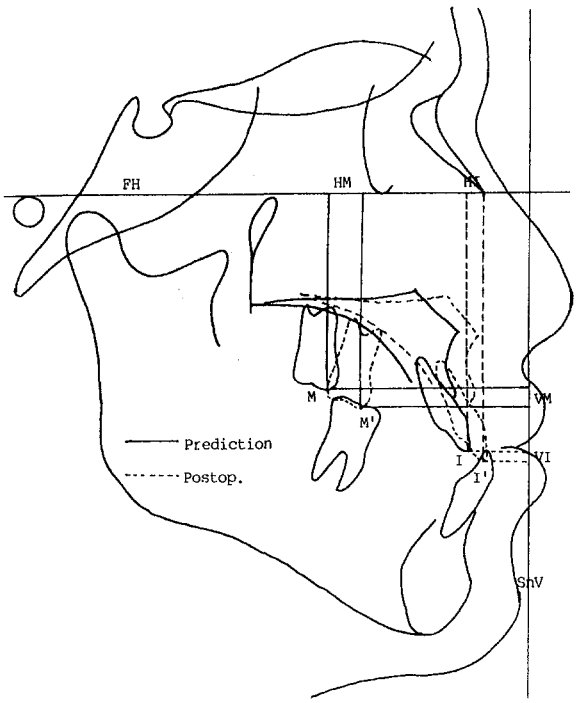

Figure 2. Illustration of landmarks and measurements on lateral cephalogram

FH(Frankfort Horizontal plane); a horizontal plane tangent to Porion and Orbitale

SnV(Sn Vertical plane); a vertical plane tangent to Sn and perpendicular to FH plane

I; the incisal edge of maxillary cental incisor on prediction tracing

I'; the incisal edge of maxillary cental incisor on postoperative tracing

M; the mesial cusp tip of maxillary first molar on prediction tracing

M; the mesial cusp tip of maxillary first molar on postoperative tracing

The measurements analyzed were as follows:

VI; a vertical distance from I to I' parallel to SnV

VM; a vertical distance from M to M' parallel to SnV

HI; a horizontal distance from I to I' parallel to FH plane

HM; a horizontal distance from M to M' parallel to FH plane

Positive measures for vertical change was acknowledged to be the inferior displacement and positive for horizontal change as the anterior displacement. All measures were analyzed by Computer scanner and comparison was made between the predicted and the actual surgical movements in the horizontal and vertical direction using paired t-test.

(2) Postero-Anterior Cephalograms:

10 of 17 patients were possible to superimpose the predicted tracings on the postoperative tracings in P-A cephalograms. All essential skeletal and dental structures of predicted and postoperative P-A cephalogrms were traced on the acetate paper by one investigator and these were superipmposed each other by means of cranial base superimposition. The orbital plane was used as the reference plane, and point references and measurments were used to evaluate post operative changes of maxillary dental midline and errors in canting correction as illustrated in Figure-3 as follows:

C; the contact point between right and left maxillary central incisors on prediction tracings

C'; the contact point between right and left maxillary central incisors on postoperative tracings

L; the buccal cusp tip of the left maxillary first molar on prediction tracings

L'; the buccal cusp tip of the left maxillary first molar on postoperative tracings

R; the buccal cusp tip of the right maxillary first molar on prediction tracings

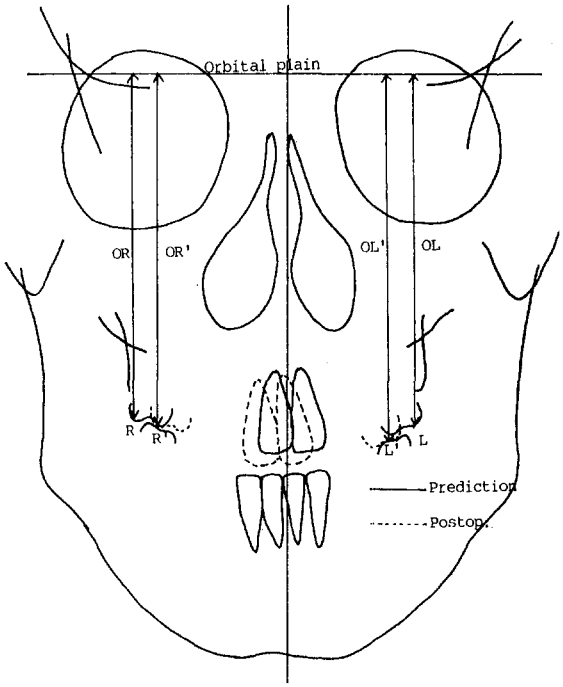

Figure 3. Illustration of landmarks and measurements on P-A cephalogram

R' ; the buccal cusp tip of the right maxillary first molar on postoperative tracings

OP(Orbital plane) ; a plane tangent to right and left Supraorbitale

OR(OL) ; a perpendicular distance from point R (L) to OP on prediction tracings

OR'(OL') ; a perpendicular distance from point R' (L') to OP on postoperative tracings

OR - OL ; the canting difference between right and left maxillary first molars on the prediction tracings

OR' - OL' ; the canting difference between right and left maxillary first molars on the postoperative tracings

(OR - OL)/(OR' - OL') ; the canting difference between the prediction and postoperative tracings

C - C' ; the amount of change of maxillary dental midline between the prediction and postoperative tracings

Positive measures for the change of maxillary dental midline was acknowledged to shift to left. All measures were analyzed by Computer scanner and comparison was made between the predicted and the actual surgical movements in the horizontal and vertical direction using paired t-test.

Ⅳ. RESULTS

A. Lateral Cephalograms(Table - Ⅰ)

(1) Vertical changes of the maxilla

The mean difference between the predicted and postoperative actual vertical position of the maxillary incisor(VI) was 1.06㎜(SD=1.54 ; $p>0.05$). There were no significant difference between the predicted and actual changes. Ten patients had a difference lesser than 1.0㎜, and only one patient had a difference greater than 4.0㎜. The actual position of the maxillary incisor had a slight tendency to locate more inferiorly than predicted position in general.

The mean difference between the predicted and actual vertical position of the maxillary molar(VM) was 1.29㎜(SD=1.00 ; $p>0.05$) and there were not significant differences. This differenes varied from 0 to 3.10㎜, but the actual position of the maxillary molar had a tendency to locate more inferiorly than predicted position in general(11 cases ; 64.7%).

(2) Horizontal changes of the maxilla

The mean difference between the predicted and actual horizontal position of the maxillary incisor(HI) was 1.34㎜(SD=0.83 ; $p<0.05$). There were significant differences between the predicted and the actual changes. Five cases had a difference within 1㎜, and the largest difference was 3.10㎜. The actual position of the maxillary incisor molar had a tendency to locate more anteriorly than predicted position in general(10 cases ; 58.8%)

The mean difference between the predicted and actual horizontal position of the maxillary molar (HM) was 1.40㎜(SD=1.09 ; $p>0.05$). There were significant differences. One case showed the maximum difference of 4.45㎜ and actual position had a tednecy to locate more anteriorrly than predicted one.

Table - I. Positional Changes of the Maxilla on Lateral Cephalograms

patient	Movement	VI	HI	VM	HM(mm)
1	PI	0.05	2.50	1.10	1.55
2	Ad	0.00	−1.00	1.00	−2.20
3	PI	0.70	1.55	−0.80	2.10
4	Ad+Seg	0.00	−1.55	1.55	−1.80
5	CC	0.90	0.00	0.00	0.00
6	PI+Seg	1.10	1.00	3.00	2.75
7	PI	0.00	0.00	0.00	0.00
8	Seg	−0.35	2.70	−0.30	1.30
9	PI+Seg	2.30	1.70	2.00	2.10
10	CC+DG	0.00	−0.65	−0.20	−0.90
11	CC	4.10	−1.00	0.85	−1.00
12	SR	2.10	3.10	1.30	4.45
13	PI+DG	0.10	1.40	0.80	1.60
14	PI	1.45	1.50	3.00	1.50
15	CC+PI	−2.65	−1.00	−3.10	−0.90
16	PI	1.25	0.50	2.10	0.10
17	PI	0.90	1.60	0.80	1.50

* Mean difference : VI = 1.06 ± 1.13mm (S.D. = 1.54 $p>0.05$)
VM = 1.29 ± 1.00mm (S.D. = 1.00 $p>0.05$)
HI = 1.34 ± 0.83mm (S.D. = 0.83 $p<0.05$)
HM = 1.40 ± 1.09mm (S.D. = 1.09 $p<0.05$)

PI = posterior impaction Ad = advancement
CC = canting correction DG = down - grafting
SR = Superior repositioning Seg = two or more segmented

Table - II. Positional Changes on Posteroanterior Cephalograms

patient	Movement	OR - OL	OR' - OL'	(OR - OL) − (OR' - OL')	C - C'(mm)
1	CC	0.0	1.0	−1.0	−0.7
2	CC	−2.0	−3.0	1.0	−1.0
3	CC+PI	6.0	3.0	3.0	4.0
4	CC+DG	0.0	0.0	0.0	−1.0
5	PI	1.0	1.0	0.0	−1.0
6	PI	0.5	0.5	0.0	−3.0
7	PI	−1.0	−2.0	1.0	2.0
8	PI+DG	−1.0	0.5	−1.5	−0.2
9	AD	1.5	1.0	0.5	1.0
10	PI	−0.5	−1.0	0.5	−1.7

* Mean difference : (OR - OL) − (OR' - OL') = 0.85 ± 0.46mm (S.D. = 0.46)
C - C' = 1.29 ± 0.83mm (S.D. = 0.83)

PI = posterior impaction Ad = advancement
CC = canting correction DG = down - grafting

B. P-A Cephalograms(Table-II)

(1) Canting difference(OR-OL/OR'-OL')

The mean difference of canting amount between the predicted and actual canting corrention of the maxilla was 0.85㎜(SD=0.46). In Eight cases, the canting amount was within 1.0㎜ on postoperative results. Only one case showed remakable postoperative canting change of 3.0㎜

(2) Midline difference(C-C')

The mean difference of the maxillary dental midline between the perdiction and actual postoperative position was 1.29㎜(SD=0.83). And actual position of it had a little tendency to shift right in general(7/10)

V. DISCUSSION

When we move both upper and lower jaws simultaneously into their new positions for orthognathic purpose, an accurate position of the maxilla as same as prediction must be established intraoperatively at first because reposition of the mandible will be followed by reposition of the maxilla. To achive this purpose, precise model surgery for production of intermediate splint which will serve as a key wafer of three-dimensional change of the maxilla between osteotomized maxilla and unoperated mandible, and precise methods for measuring spatial change of the repositioned maxilla during surgery must be fulfilled in accuracy, There are two ways to measure and determine maxillary movements during surgery: Internal measuring technique(IMT) and External measuring technique(EMT).

Internal measuring technique has been used commonly until now, however several authors have been described its problems in practical efficacy and accuacy. Polido et al[5] performed a study on predictability of maxillary surgery by means of internal measurements on 100 patients recently and assessed the difference between the predicted and actual surgical movements. The horizontal mean errors were 1.77± 1.5㎜ in maxillary central incisors and 2.0± 1.57㎜ in first molar, and vertical mean errors were 2.16± 1.54㎜ and 1.73± 0.54㎜ each. The statistical analysis showed signicant difference between the predicted and actual changes, and therefore, they concluded that the use of arbitrary internal reference landmarks on maxillary wall was not an accurate method to establish maxillary repositioning as same as prediction.

To correct these faults and to obtain a more precise intraoperative measurements, external measuring technique was introduced. In 1985, Johnson[3] performed a horizontal suture in the skin around soft tissue nasion area and using it as a reference point measured the distance between this point and the tip of the maxillary central incisor pre-and postoperatively and succeeded repositioning the maxilla. In 1986, Van Sickels et al[6] used adhesive tapes on nasal bridge area and incisal edges of maxillary central as external measuring points. In 1987, Heggie[2] invented an external three-point calibrator consistiong of three measuring points on upper incisor, nasal bridge and frontal bone to obtain more precise intraoperative horizontal and vertical measurements. The soft tissue reference may not useful to calculate real distance between it and osseous reference(maxillary cental incisor) because it can be moved easily depend on manipulation of underlying osseous structures for repositioning. So recently, a K-wire inserted directly into the bone at frontonasal suture area is used as a stable measuring point to prevent errors made by soft-tissue mobility(Figure 1).

Van Sickels et al[6] conducted both internal and external measurements on 11 subjects and compared the vertical and horizontal errors in the maxillary incial edge on the lateral cephalograms. Their result showed that vertical error was 2.5± 1.6㎜ in internal measuring and 0.7± 0.6㎜ in external measuring, and horizontal error was 3.6± 1.6㎜ and 1.1± 0.6㎜ each. According to these, the external measurement had significantly less differences between the predicted and postoperative positions than the internal measurment.

The result of our study showed the mean difference of vertical and horizontal change in maxillary

central incisors as 1.06± 1.13㎜(S.D. =1.54 P>0.05) and 1.34± 0.83㎜(S.D. =0.83 P<0.05). It was little more error than the result of external measuring technique conducted by Van Sickels et al[6] but much less error compared to the result of internal measuring technique by Polido et al[5]. Our result in maxillay first molar showed the mean difference of vertical and horizontal change as 1.29± 1.00㎜(S.D. =1.00 P>0.05) and 1.40± 1.09㎜(S.D. =1.09 P<0.05). We cannot compared this result exactly with any other reports but it was much less error than the result of internal measuring technique by Polido et al[5]. In our study, positional error in molars was more than incisors, however its difference was little.

As a result of t-test analysis in our study between the predicted and actual movement of vertical and horizontal change in incisors and molars by EMT, there were no significant difference in vertical change but significant differnece in horizontal change in both incisors and molars. In EMT practically, the vertical change of maxillary incisor can be controlled directly by measuring on caliper, however, the horizontal change of incisor and the horizontal and vertical change of molar would be affected passively by several factors such as model surgery, intermediate splint made by model surgery, condylar movements on digital manipulation when osteotomized maxilla fixed to the cranial part, and so on. Therefore, the vertical change of incisors is possible to make as same as prediction but others cannot be controlled actively during surgery. Our result of t-test also showed same phenomena definitely as described above. Errors in the vertical change of maxillary incisors was the smallest and the horizontal change of maxillary first molar was the largest. Van Sickels et al[6] also described that the vertical change showed less inaccuracy than horizontal change. Mean differneces of all changes were less than 1.5㎜ in our study and they are less than Polido's result by IMT[5].

During our surgery we did not use any internal measuring landmarks but moved the osteotomized maxilla only by EMT. So, we had been some questions as follows: Does manual autorotation of the mandible in supine position change the transverse plane of the maxilla? Does canting correction is confidential by EMT only in asymmetric maxilla? Whether a midline of maxillary dentition would be affected by manual movement of the mandible? To get some predictable informations about above questions, we used P-A cephalograms and studied differences of the transverse plane and midline change between predicted and actual movement of the maxilla. Mean difference of the transverse palne on P-A cephalograms[(OR-OL)−(OR'-OL')]was 0.85± 0.46㎜(S.D. =0.46) and eight of ten cases were less than 1.0㎜ error on the transverse plane. We suggest this result showed that maxillary movement by manual autorotation of the mandible would not influnece to change the transverse plane of the maxilla, and canting correction might be confidential in EMT. However it cannot be overlooked that the successful results of this study was not only to depend on the correlation with EMT, but adequate preoperative prediction and model works for making of intermediate splint.

Mean error of maxillary dental midline(C-C') was remarkable as 1.29± 0.83㎜(S.D. =0.83) and showed the tendency to be displaced to the right direction(8 of 10). This result means that maxillary dental midline is the most unpredictable position when we use EMT. Orthdontically and esthetically, the ideal position of maxillary dental midline to facial midline is the most important. Therefore, Any methods may be neccessary to make predictable maxillary dental midline during surgery. The right-shifting tendency of the maxillary dental midline of our result may be due to the uneven push force using digital pressure drawn by surgeon who positioned to the right side of the patient. Even and constant distribution of the digital force should by applied more carefully when the mandible is autorotated by digital manipulation upwardly with maxilla which was fixed onto the mandible with intermediate splint by intermaxillary fixation.

We analyzed tendency of the maxillary movement to reposition. Putting the results of lateral and P-

A cephalogram together, the actual maxillary movement showed the tendency to reposition itself anteriorly and inferiorly.

Ⅵ. SUMMARY

The following results had been achieved through comparative analysis between preoperative prediction and postoperative actual movement in seventeen patients who underwent "simultaneously two-jaw surgery" using external measuring technique during the period of Sep. 1988 to Sep. 1990.

1. The vertical mean differences between prediction and actual change were 1.06± 1.13㎜ in incisors, 1.29± 1.00㎜ in molars, and had the tendency to displace inferiorly(87%)
2. The horizontal mean differences between prediction and actual change were 1.34± 0.83㎜in incisors, 1.40± 1.09㎜ in molars, and had the tendency to displace anteriorly(58.8%),.
3. The mean difference of the transverse plane between prediction and actual change was 0.85± 0.46㎜.
4. The mean difference in maxillary midline change was 1.29± 0.83㎜, and had the right-shifting tendency(70.0%).

In summary, our results on the external measurement technique(EMT) had less error in the vertical and horizontal direction to move maxilla into its predicted position compared with the results of internal measurement technique(IMT) in other literature. Errors in vertical change was less than errors in horizontal change and transverse plane was not affected by digital manupliaon by surgeon. However, postoperative position of the maxilla was placed more anteriorly and inferiorly in overall direction. Change of the maxillary dental midline was large and had right-shifting tendency. Therefore, the precise methods to keep maxillary dental midline as prediction and the avoidance of uneven force applied to the mandible for autorotation should be necessary during surgery.

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국문초록

외부계측법에 의한 상악골 이동의 위치적 정확도에 대한 평가 연구

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하악골의 발육이상과 더불어 상악골의 수평적 및 수직적 발육이상이 동반되어 있는 대부분의 악안면 기형 환자에서 상하악골을 동시에 재위치시키는 "상하악골 동시 이동 수술"은 현재 악교정 수술에서 보편화되어 있는 술식이므로, 이 경우 수술중에 일차로 상악골의 정확한 위치를 얻는 것이 매우 중요하다.

Le Fort I 수평골절단술을 이용한 상악골의 재위치시 위치 이동의 정확성을 기하기 위하여 고전적으로 사용되어온 계측방법인 내부계측법(Intrnal measuring technique)은 최근에 이르러 계측상의 삼차원적 오차에 따른 정확도에 많은 의문이 제기되어 왔으며, 따라서 이를 보완하기 위하여 1985년 Johnson이 처음으로 외부계측법(External measuring technique)을 소개한 이후로, Van Sickels 등의 여러 학자들에 의하여 그 사용의 유용성 및 정확성이 입증되어 왔다.

이에 저자등은 최근 2년간 본 교실에서 경험한 상·하악골동시이동 악교정수술환자중, 외부계측법에만 의존하여 상악골 이동량을 술중 계측했던 17명의 환자에서 수술전 이동계측량과 수술후 이동된 결과를 Lateral cephalometics상에서 전치부와 구치부의 수직 및 수평적 이동 오차 관계로, P-A cephalogram 상에서 수평적 이동 및 상악치열의 중심선 변위에 대한 이동 오차 관계로 분석하여 외부계측법에 의한 수술적 이동의 정확도를 평가하므로써 향후 이 방법의 사용에 대한 신뢰성을 보고자 본 연구를 시행하였다.

연구 결과로써, 상악골의 수직 및 수평적 이동시 외부계측법 만을 이용한 경우, 수술전 이동량에 비해 비교적 신뢰성 있게 상악골을 원하는 위치로 이동시킬 수 있는 것으로 사료되나, 대체적으로 전하방 및 우측으로 위치되기 쉬운 경향을 보여주었으며, 정면상의 수평기울기(transverse plane)에 대한 편차는 수술자에 의해 크게 영향을 받지 않았으나 상악치열의 중심위는 수술자에 의해 영향을 받은것 같다.