# 치과교정학분야에서의 인공지능 기술의 적용

## : 치과의사가 덕질로 직접 만든 교정전문 AI

치과교정과 전문의 김예현

치과교정과 전문의

# 김예현

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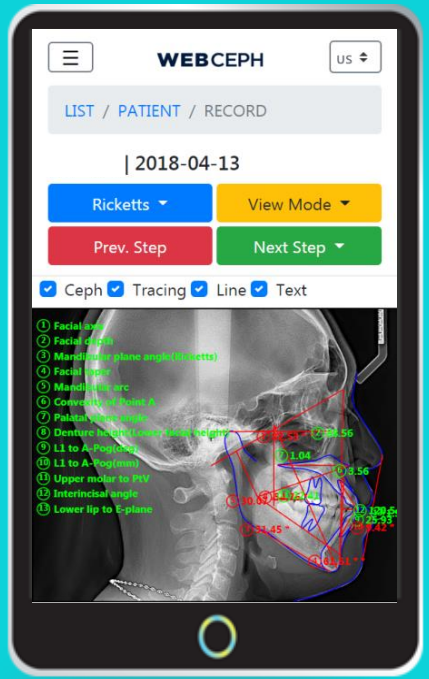
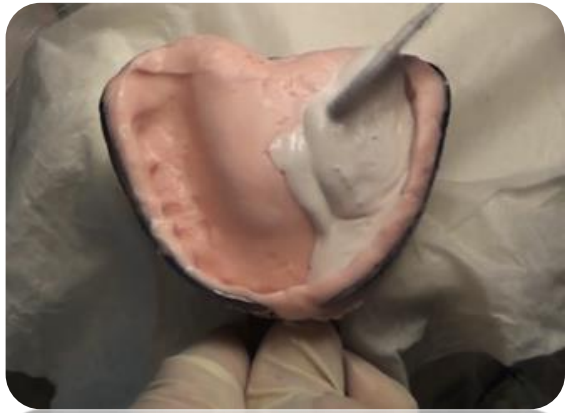
WEBCEPH

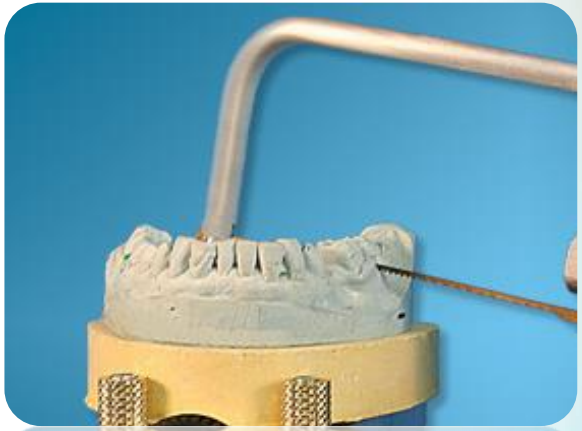


# 발표 개요

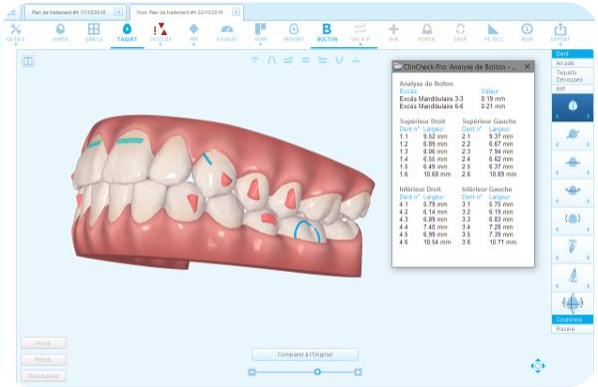
1. 디지털 기술의 도입에 따른 치과교정학의 변화
2. 인공지능이 변화시킬 치과교정학
3. 치아교정 AI의 개발 스토리
4. 앞으로의 비전

# 과거의 치과교정학





# 현대의 치과교정학

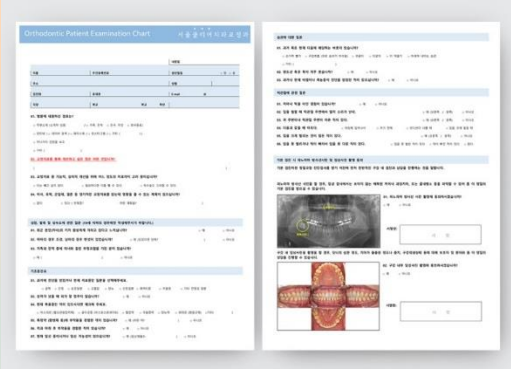


그리고....

# 치아 교정의 프로세스

1. 환자 내원
2. 진단 자료 채득
3. 진단 자료 분석, 문제목록
4. 치료 계획 수립
5. 3차원 구강스캔자료 전송
6. 3차원 치아이동 시뮬레이션
7. 교정 장치 제작 및 배송
8. 교정 치료 시작

# 진단자료 채득

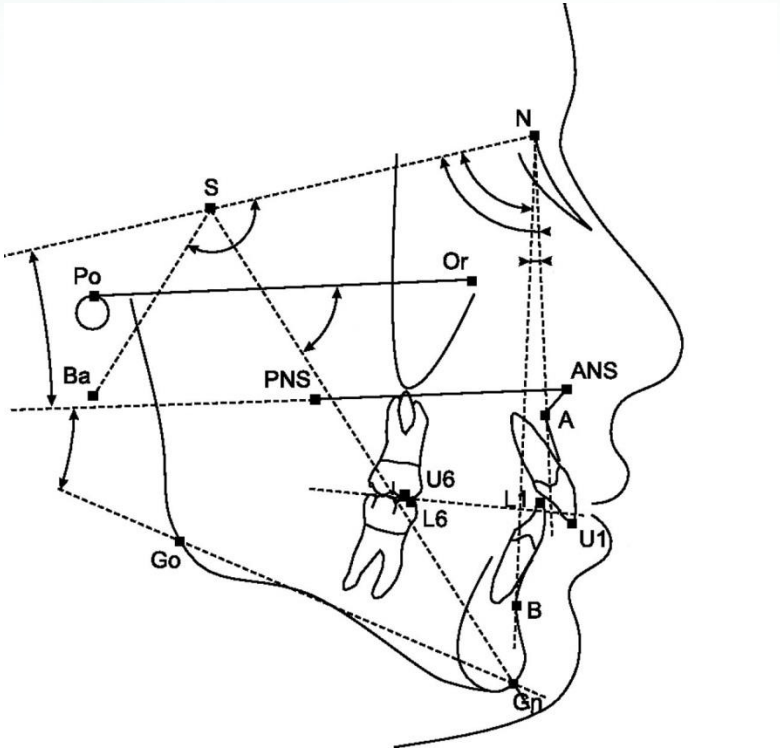

Orthodontic Patient Examination Chart

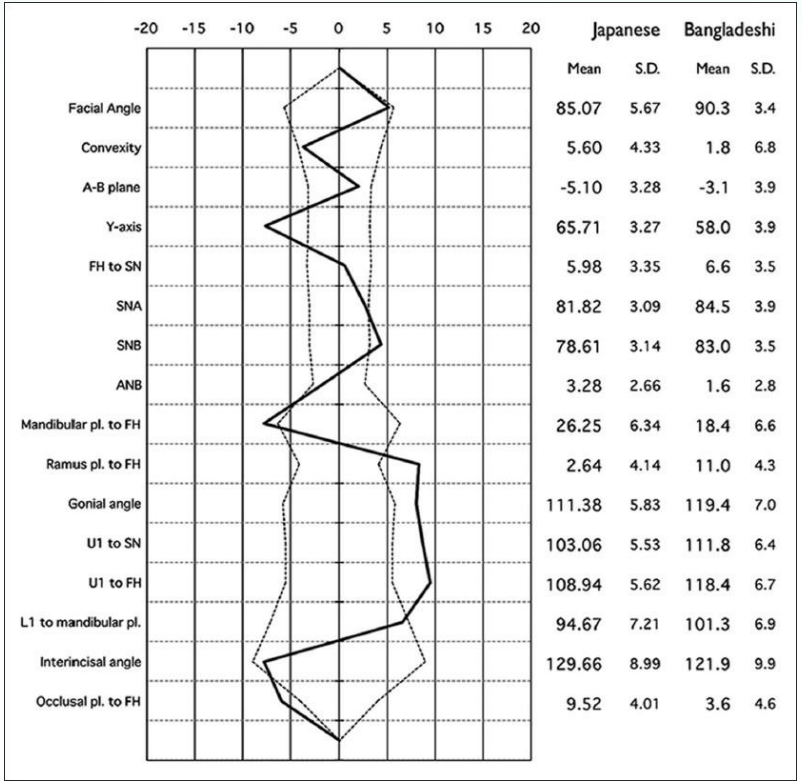

환자 ID: 05020501
이름: 김, 예현
성별: 남자
나이: 37 세, 0 개월


서울 클리어 치과교정과 치과의원
SEOUL CLEAR ORTHODONTIC

# 진단 자료 분석 : Cephalometric Analysis

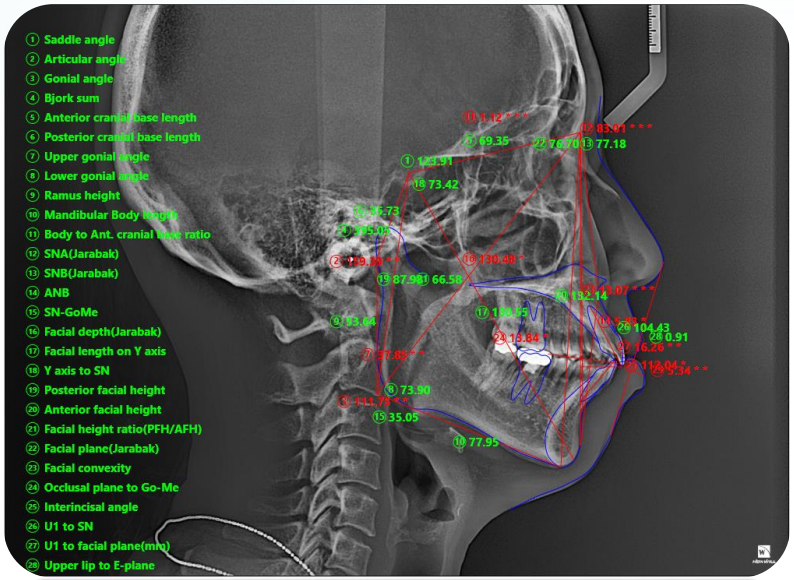
# 진단 자료 분석 : Cephalometric Analysis




| | Japanese | | Bangladeshi | |
|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. |
| Facial Angle | 85.07 | 5.67 | 90.3 | 3.4 |
| Convexity | 5.60 | 4.33 | 1.8 | 6.8 |
| A-B plane | -5.10 | 3.28 | -3.1 | 3.9 |
| Y-axis | 65.71 | 3.27 | 58.0 | 3.9 |
| FH to SN | 5.98 | 3.35 | 6.6 | 3.5 |
| SNA | 81.82 | 3.09 | 84.5 | 3.9 |
| SNB | 78.61 | 3.14 | 83.0 | 3.5 |
| ANB | 3.28 | 2.66 | 1.6 | 2.8 |
| Mandibular pl. to FH | 26.25 | 6.34 | 18.4 | 6.6 |
| Ramus pl. to FH | 2.64 | 4.14 | 11.0 | 4.3 |
| Gonial angle | 111.38 | 5.83 | 119.4 | 7.0 |
| U1 to SN | 103.06 | 5.53 | 111.8 | 6.4 |
| U1 to FH | 108.94 | 5.62 | 118.4 | 6.7 |
| L1 to mandibular pl. | 94.67 | 7.21 | 101.3 | 6.9 |
| Interincisal angle | 129.66 | 8.99 | 121.9 | 9.9 |
| Occlusal pl. to FH | 9.52 | 4.01 | 3.6 | 4.6 |

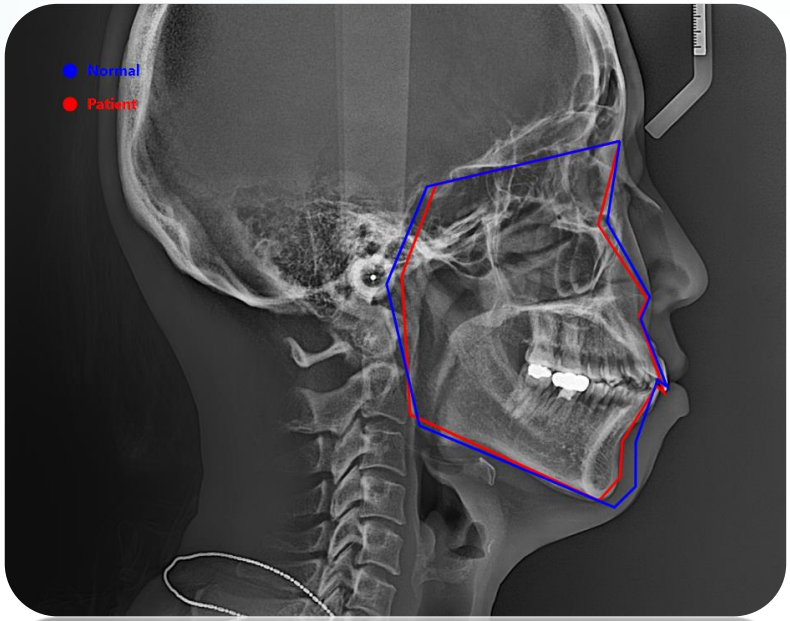
# 진단 자료 분석 : Cephalometric Analysis




## Method I analysis

| Measurement | Mean | S.D. | Result | Severity | Polygonal chart | Meaning |
|---|---|---|---|---|---|---|
| Saddle angle | 125.45 | 5.3 | 123.91 | | 120 125 130 135 | Saddle angle within normal range |
| Articular angle | 147.68 | 5.3 | 159.39 | * * | 140 145 150 155 | Obtuse articular angle, Dolichocephalic facial type |
| Gonial angle | 124.31 | 5.4 | 111.75 | * * | 115 120 125 130 135 | Acute gonial angle |
| Bjork sum | 397.16 | 3.6 | 395.05 | | 390 395 400 405 | Normodivergent Skeletal Pattern |
| Anterior cranial base length | 69.35 | 3.6 | 69.35 | | 60 65 70 75 80 | Normal anterior cranial base length |
| Posterior cranial base length | 37.68 | 2.7 | 35.73 | | 30 35 40 45 50 | Normal posterior cranial base length |
| Upper gonial angle | 46.2 | 3.3 | 37.85 | * * | 35 40 45 50 55 | Mandible is growing down and backward. |
| Lower gonial angle | 78.04 | 4.6 | 73.90 | | 70 75 80 85 | Normal lower gonial angle |
| Ramus height | 49.07 | 4.9 | 53.64 | | 40 45 50 55 | Normal ramus height |
| Mandibular Body length | 74.97 | 4.9 | 77.95 | | 65 70 75 80 85 | Normal mandibular body length |
| Body to Ant. cranial base ratio | 1.08 | 0.0 | 1.12 | * * * | -10 -5 0 5 10 15 | Large mandibular body length relative to cranium |
| SNA | 81.08 | 3.7 | 83.01 | | 70 75 80 85 90 | Normal A-P position of maxilla |
| SNB | 79.17 | 3.8 | 77.18 | | 70 75 80 85 90 | Normal A-P position of mandible |
| ANB | 2.46 | 1.8 | 5.83 | * | -10 -5 0 5 10 15 | Skeletal Class II |
| SN-GoMe | 34.29 | 6.4 | 35.05 | | 30 35 40 | Normodivergent facial pattern |
| Facial depth(Jarabak) | 123.27 | 5.1 | 130.48 | * | 115 120 125 130 | Large facial depth(Na-Go distance) |
| Facial length on Y axis | 130.29 | 7.9 | 130.55 | | 124 126 128 130 132 134 136 | Normal facial length on Y-axis(S-Gn) |
| Y axis to SN | 71.92 | 3.7 | 73.42 | | 65 70 75 80 | Normodivergent vertical growth pattern |
| Posterior facial height | 82.76 | 5.3 | 87.98 | | 75 80 85 90 | Normal posterior facial height |
| Anterior facial height | 128.68 | 6.3 | 132.14 | | 120 125 130 135 | Normal anterior facial height |
| Facial height ratio(PFH/AFH) | 65.3 | 8.8 | 66.58 | | 60 62 64 66 68 70 | Normodivergent growth pattern |
| Facial plane(Jarabak) | 78.82 | 4.0 | 76.70 | | 70 75 80 85 | Normal Chin Prominence, Skeletal Class I |
| FMA | 29.63 | 3.0 | 26.73 | | 20 25 30 35 40 | Normodivergent facial pattern |
| FMIA | 56.77 | 6.0 | 44.78 | * | 45 50 55 60 65 | Proclined lower incisor relative upper face |
| IMPA | 91.62 | 3.2 | 108.49 | * * * | 80 90 100 | Proclined lower incisor |
| Interincisal angle | 125.44 | 9.2 | 112.04 | * | 115 120 125 130 135 | Proclined incisors, Dentoalveolar protrusion |
| L1 to mandibular plane | 46.4 | 3.6 | 36.24 | * * | 35 40 45 50 55 | Under-erupted lower incisors |
| U1 to FH | 113.8 | 6.4 | 112.75 | | 110 115 120 | Normal upper incisor inclination |

# 진단 자료 분석 : Cephalometric Analysis




## Method I analysis

| Measurement | Mean | S.D. | Result | Severity | Polygonal chart | Meaning |
|---|---|---|---|---|---|---|
| Saddle angle | 125.45 | 5.3 | 123.91 | | 120 125 130 135 | Saddle angle within normal range |
| Articular angle | 147.68 | 5.3 | 159.39 | * * | 140 145 150 155 | Obtuse articular angle, Dolichocephalic facial type |
| Gonial angle | 124.31 | 5.4 | 111.75 | * * | 115 120 125 130 135 | Acute gonial angle |
| Bjork sum | 397.16 | 3.6 | 395.05 | | 390 395 400 405 | Normodivergent Skeletal Pattern |
| Anterior cranial base length | 69.35 | 3.6 | 69.35 | | 60 65 70 75 80 | Normal anterior cranial base length |
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| Body to Ant. cranial base ratio | 1.08 | 0.0 | 1.12 | * * * | -10 -5 0 5 10 15 | Large mandibular body length relative to cranium |
| SNA | 81.08 | 3.7 | 83.01 | | 70 75 80 85 90 | Normal A-P position of maxilla |
| SNB | 79.17 | 3.8 | 77.18 | | 70 75 80 85 90 | Normal A-P position of mandible |
| ANB | 2.46 | 1.8 | 5.83 | * | -10 -5 0 5 10 15 | Skeletal Class II |
| SN-GoMe | 34.29 | 6.4 | 35.05 | | 30 35 40 | Normodivergent facial pattern |
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| Anterior facial height | 128.68 | 6.3 | 132.14 | | 120 125 130 135 | Normal anterior facial height |
| Facial height ratio(PFH/AFH) | 65.3 | 8.8 | 66.58 | | 60 62 64 66 68 70 | Normodivergent growth pattern |
| Facial plane(Jarabak) | 78.82 | 4.0 | 76.70 | | 70 75 80 85 | Normal Chin Prominence, Skeletal Class I |
| FMA | 29.63 | 3.0 | 26.73 | | 20 25 30 35 40 | Normodivergent facial pattern |
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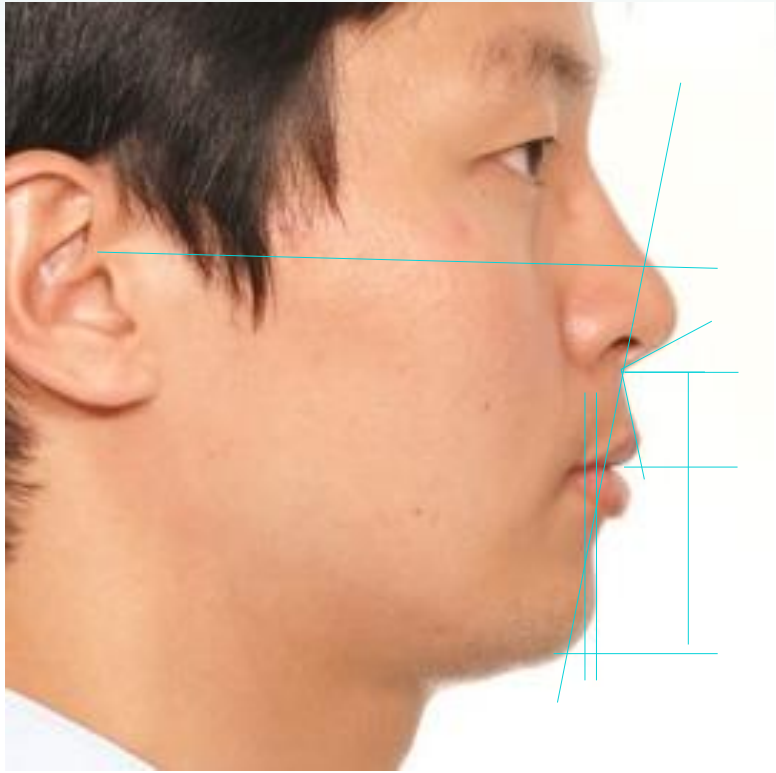
| U1 to FH | 113.8 | 6.4 | 112.75 | | 110 115 120 | Normal upper incisor inclination |

# 진단 자료 분석: 측모 연조직 분석



**Soft tissue Analysis**

1. N′Pog′ to FH = 90.5 (91±2)

2. B′ to Pog′ = 1.8 (1.5)

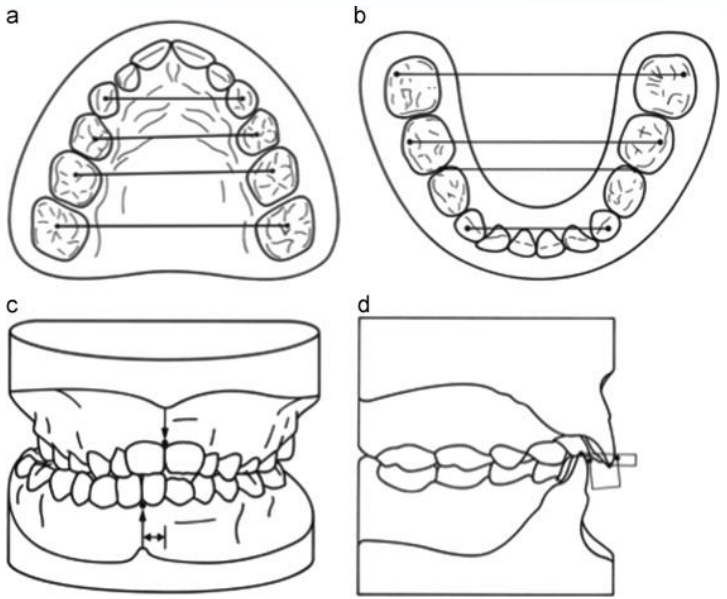
3. FH to A′B′ = 80 (81)

4. Soft tissue prominence to A′B′
   = 4 : 1.8 : 2.0 : 1.0 (4:2:2:1)

5. Nasolabial angle 19/80 (20/80)

6. Sn – Ustm : LStm – Me
   = 1:2.0 (1:1.8~2)

# 진단 자료 분석: 치아 모델 분석



# 진단 자료 분석: 치아 모델 분석

## Model Analysis

**Dentition :** Permanent
**Angle Classification :** Left : Class I
Right : Class I

**Overbite :** 2.38 mm
**Overjet :** 2.87 mm

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| | 평 균 | 편 차 |
|---|---|---|
| 중 절 치 | 8.55 | 9.67 |
| 측 절 치 | 7.00 | 6.58 |
| 견 치 | 8.01 | 8.54 |
| 제1소구치 | 7.38 | 8.37 |
| 제2소구치 | 6.86 | 7.37 |
| 제1대구치 | 10.58 | 10.85 |
| 제2대구치 | 9.79 | 10.27 |

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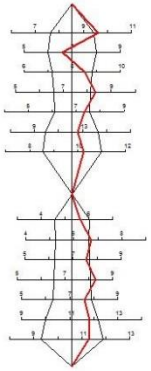
| | 평 균 | 편 차 |
|---|---|---|
| 중 절 치 | 5.32 | 5.68 |
| 측 절 치 | 5.94 | 6.75 |
| 견 치 | 6.98 | 7.60 |
| 제1소구치 | 7.30 | 8.28 |
| 제2소구치 | 7.11 | 7.66 |
| 제1대구치 | 11.11 | 11.87 |
| 제2대구치 | 10.62 | 11.32 |



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| | 평 균 | 편 차 |
|---|---|---|
| 치관폭경합 | 96.63 | 102.72 |
| 치열궁폭경 | 45.57 | 40.80 |
| 치열궁장경 | 38.49 | 43.73 |

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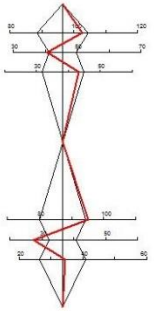
| | 평 균 | 편 차 |
|---|---|---|
| 치관폭경합 | 87.40 | 95.64 |
| 치열궁폭경 | 36.52 | 27.51 |
| 치열궁장경 | 33.79 | 34.58 |



### Transverse Analysis

| | Upper (mm) | Lower (mm) | Ratio (%) | Norm (%) |
|---|---|---|---|---|
| Intercanine width | 33.45 | 26.17 | 78.24% | 76.24 ±3.49 |
| Intermolar width | 55.07 | 44.04 | 79.97% | 84.99 ±2.65 |

### Bolton Tooth Ratio Analysis

**Overall ratio (91.3 ± 1.91)**

Sum of Mandibular 12 95.64 mm / Sum of Maxillary 12 102.72 mm X 100 = 93.11%

☐ Mx 2.03 mm deficient / ☐ Mn 1.86 mm excess

**Anterior ratio (77.2 ± 1.65)**

Sum of Mandibular 6 40.04 mm / Sum of Maxillary 6 49.56 mm X 100 = 80.79%

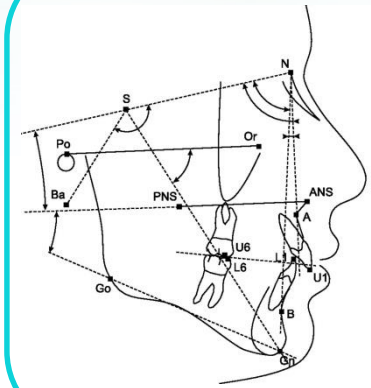
☐ Mx 2.31 mm deficient / ☐ Mn 1.78 mm excess

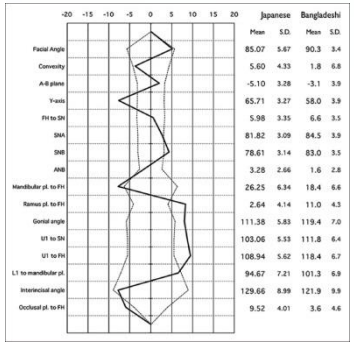
### Arch length discrepancy

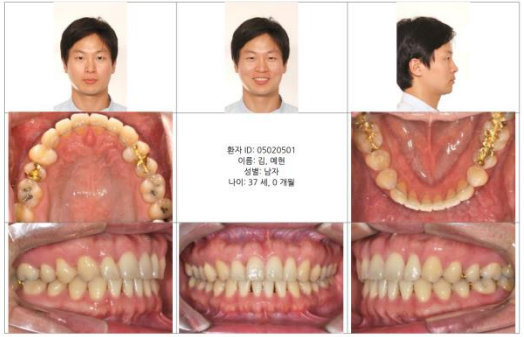
| | upper | lower |
|---|---|---|
| Available space | 77.18 | 67.23 |
| Required space | 81.03 | 71.91 |
| Arch length discrepancy | -3.85 | -4.68 |

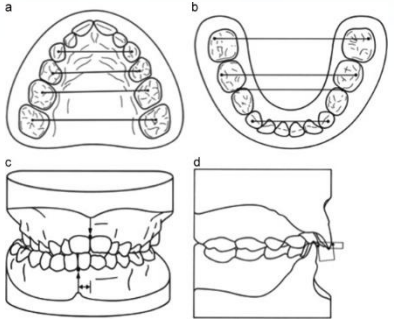
# 진단 자료 분석: 임상사진 분석

# 치료계획 수립




치료계획 수립

# 교정치료 개시

# Cephalometry Analysis using Neural Networks

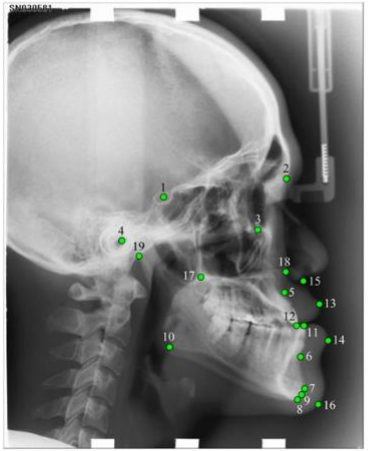
Article | OPEN | Published: 20 September 2016

## Fully Automatic System for Accurate Localisation and Analysis of Cephalometric Landmarks in Lateral Cephalograms

Claudia Lindner, Ching-Wei Wang, Cheng-Ta Huang, Chung-Hsing Li, Sheng-Wei Chang & Tim F. Cootes

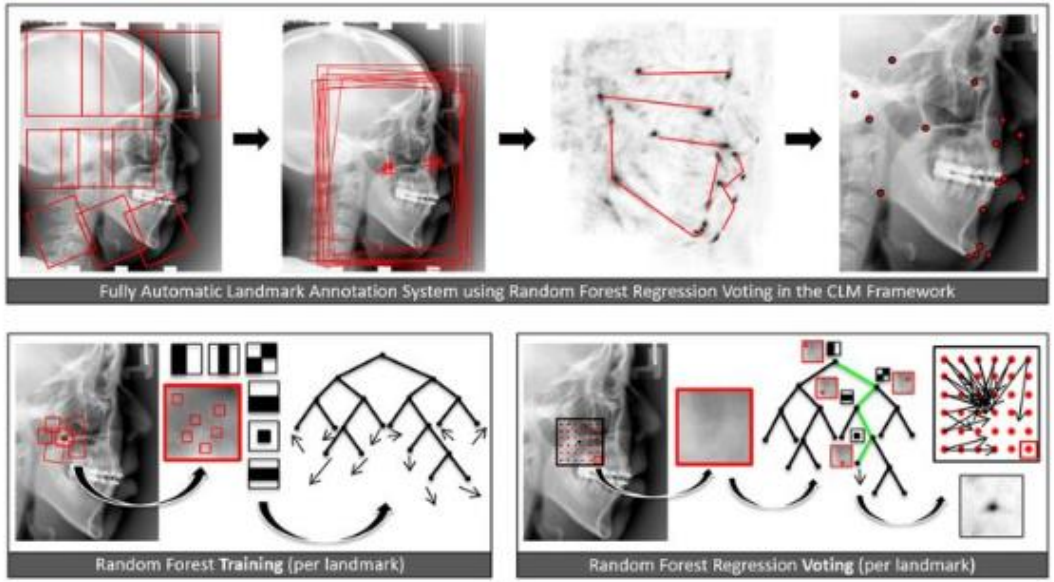
*Scientific Reports* **6**, Article number: 33581 (2016) | Download Citation

**Figure 1: Cephalogram annotation example showing the 19 landmark positions used in this study.**



L1 Sella
L2 Nasion
L3 Orbitale
L4 Porion
L5 Subspinale
L6 Supramentale
L7 Pogonion
L8 Menton
L9 Gnathion
L10 Gonion
L11 Incision inferius
L12 Incision superius
L13 Upper lip
L14 Lower lip
L15 Subnasale
L16 Soft tissue pogonion
L17 Posterior nasal spine
L18 Anterior nasal spine
L19 Articulare

**Figure 2: Schematic overview of the FALA system as described in refs 23 and 25, applied to lateral cephalograms.**



# Cephalometry Analysis using Neural Networks

## Fully automated quantitative cephalometry using convolutional neural networks

**Article (PDF Available)** · January 2017 *with* 368 Reads
DOI: 10.1117/1.JMI.4.1.014501
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**Lei Xing**
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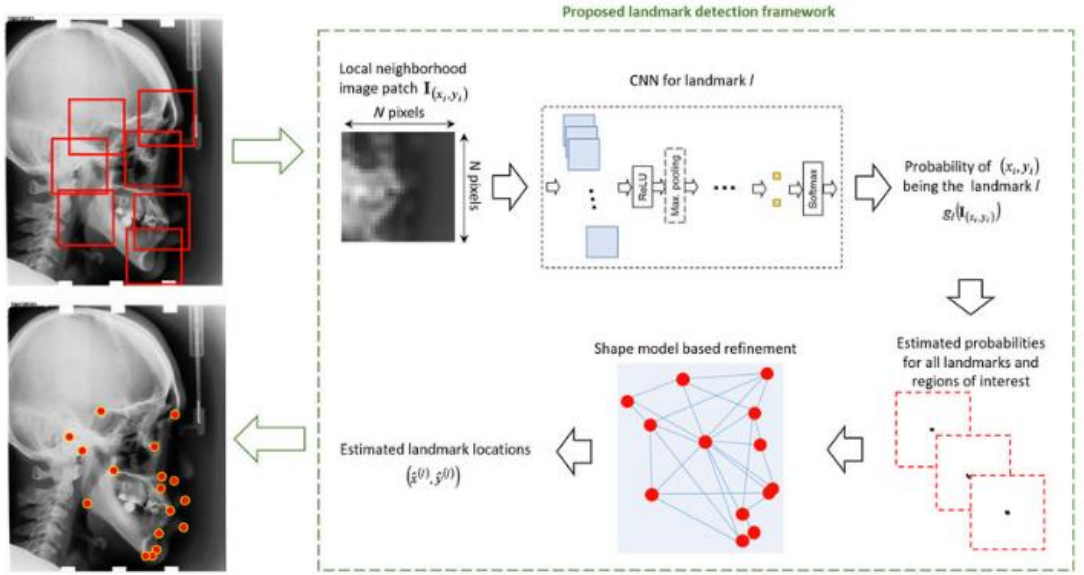


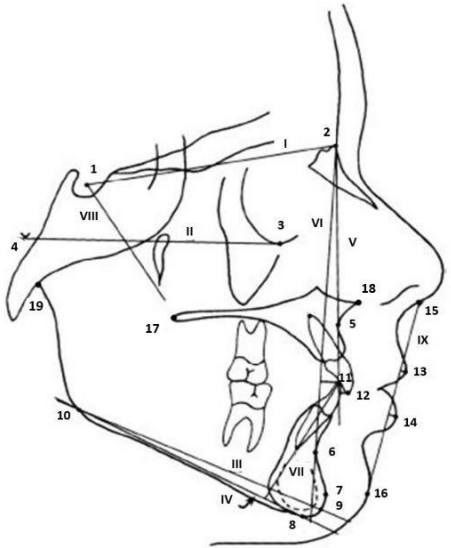

Schematics of the proposed cephalometric landmark detection framework.

# Cephalometry Analysis using Neural Networks

## Grand Challenges in Dental X-ray Image Analysis

### Challenge #1: Automated Detection and Analysis for Diagnosis in Cephalometric X-ray Image

| No. | Anatomical Landmarks |
|---|---|
| 1 | sella turcica |
| 2 | nasion |
| 3 | orbitale |
| 4 | porion |
| 5 | subspinale |
| 6 | supramentale |
| 7 | pogonion |
| 8 | menton |
| 9 | gnathion |
| 10 | gonion |
| 11 | lower incisal incision |
| 12 | upper incisal incision |
| 13 | upper lip |
| 14 | lower lip |
| 15 | subnasale |
| 16 | soft tissue pogonion |
| 17 | posterior nasal spine |
| 18 | anterior nasal spine |
| 19 | articulate |



# Treatment planning using Machine learning

TECHNO BYTES AJO-DO

## New approach for the diagnosis of extractions with neural network machine learning

**Seok-Ki Jung[a] and Tae-Woo Kim[b]**
*Ansan and Seoul, Korea*

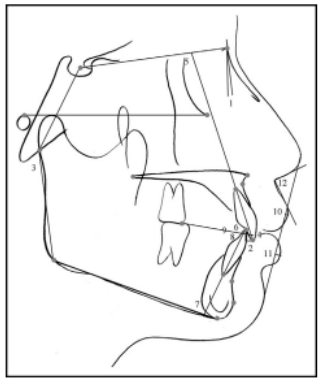


**Fig 3.** Linear and angular measurements used in this study: *1*, ANB angle; *2*, overjet; *3*, Björk sum; *4*, overbite; *5*, maxillary central incisor to SN angle; *6*, maxillary central incisor to occlusal plane angle; *7*, IMPA; *8*, mandibular central incisor to occlusal plane angle; *9*, interincisal angle; *10*, upper lip to E-line; *11*, lower lip to E-line; and *12*, nasolabial angle.

**Table II.** Descriptions for the 6 additional indexes

| *Index* | *Weighting* | *Criterion (mm)* |
|---|---|---|
| Arch length discrepancy | | |
| Spacing | 0 | ALD > 0 |
| Normal | 0.25 | −1 < ALD ≤ 0 |
| Mild crowding | 0.5 | −3 < ALD ≤ −1 |
| Moderate crowding | 0.75 | −5 < ALD ≤ −3 |
| Severe crowding | 1 | ALD ≤ −5 |
| Molar key | | |
| Class III key | 0 | |
| Super Class I key | 0.25 | |
| Class I key | 0.5 | |
| End-on key | 0.75 | |
| Class II key | 1 | |
| Large overjet | | |
| Not severe | 0 | Overjet ≤ 5 |
| Severe | 1 | Overjet > 5 |
| Protrusion | | |
| Concave profile | 0 | |
| Normal profile | 0.25 | |
| Mild protrusion | 0.5 | |
| Moderate protrusion | 0.75 | |
| Severe protrusion | 1 | |
| Chief complaint for protrusion | | |
| No protrusion in chief complaint | 0 | |
| Protrusion in chief complaint | 1 | |

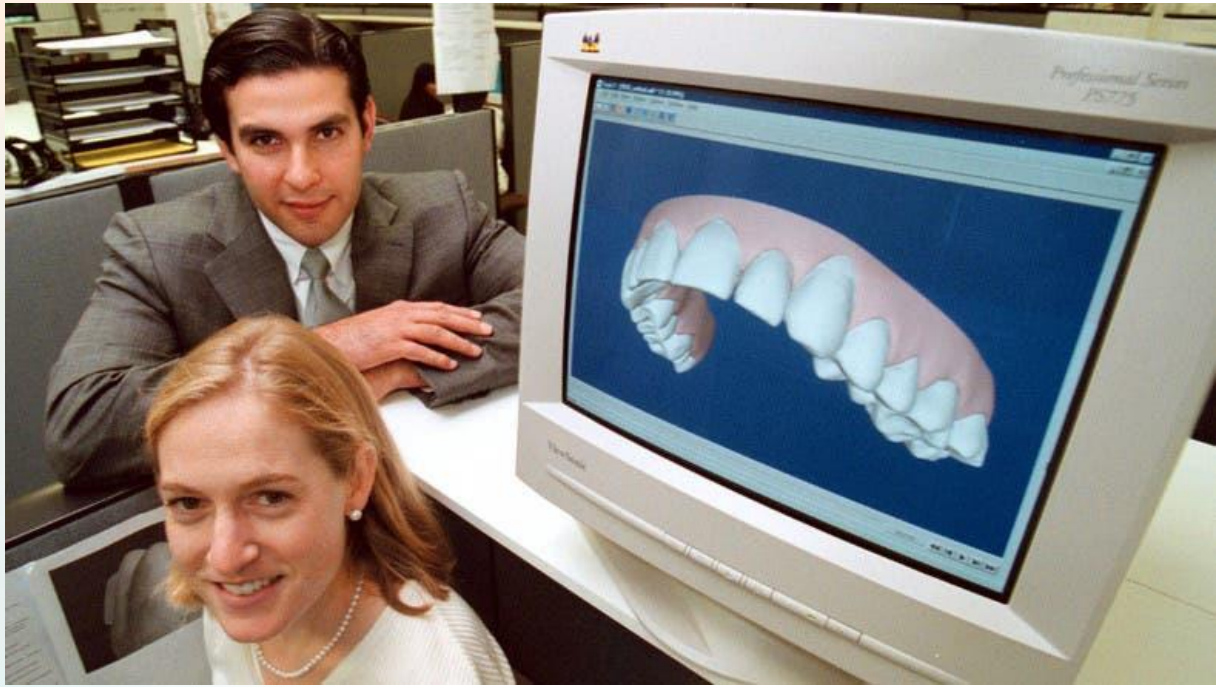
*ALD*, Arch length discrepancy.

### CONCLUSIONS

As a result of making models for the diagnosis of extractions with neural network machine learning, the success rates of the classifiers were 93% for the diagnosis of extraction vs nonextraction and 84% for the detailed diagnosis of the extraction patterns in total. This study suggests that artificially intelligence expert systems with neural network machine learning could be a new approach in orthodontics.

# 혁신은 누가 하는가?

# 교정치료환자가 교정시장 전체를 혁신하다.



Align Technology사의 창업자인 Zia Chishti와 Kelsey Wirth(출처: google.com)

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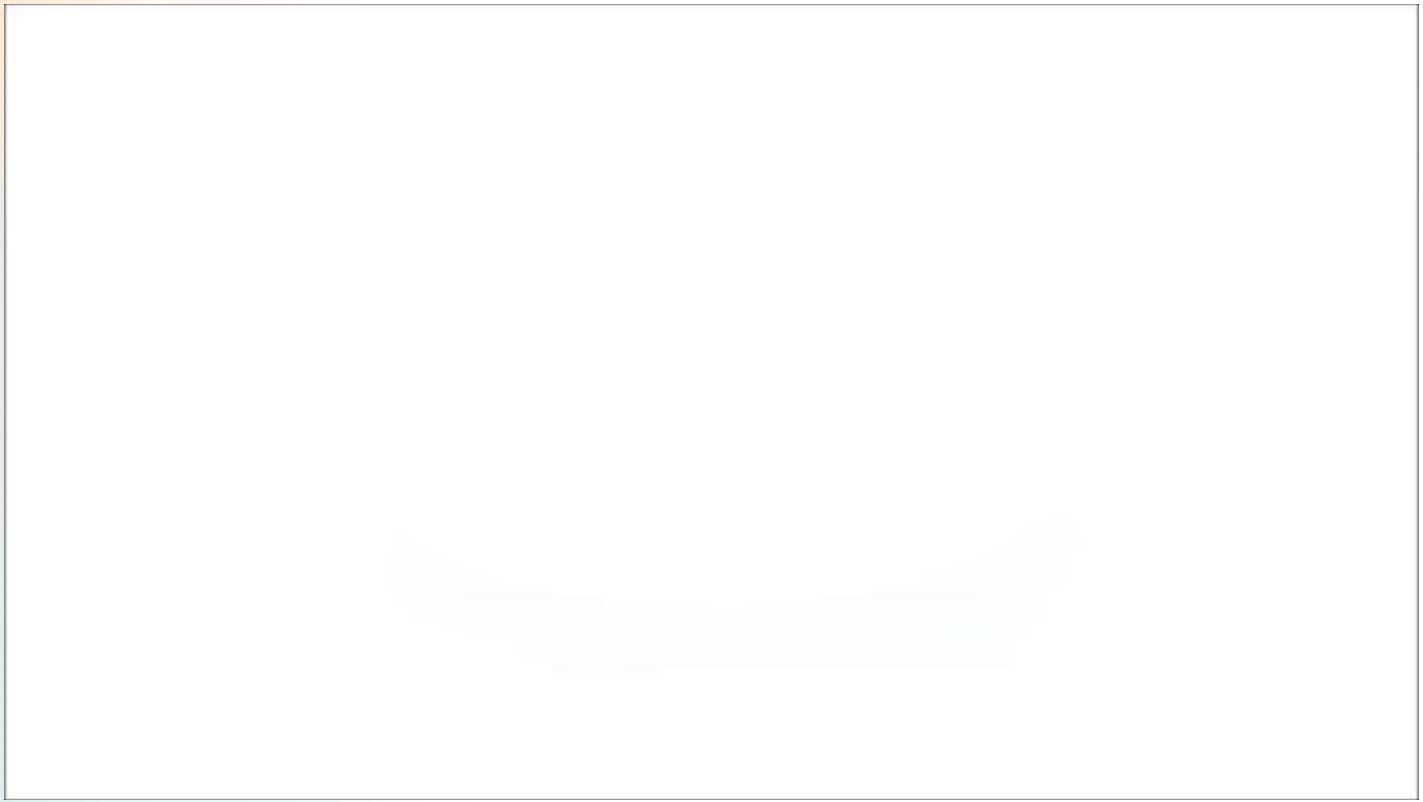

Invisalign (출처: Align Technology, google.com)

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| 최고 | 289.61 | 전일 종가 | 296.68 |
| 최저 | 272.60 | 52-주 최고 | 398.88 |
| 시가총액 | 227.49억 | 52-주 최저 | 177.92 |
| 주가수익률 | 61.31 | | |

Invisalign (출처: Align Technology, google.com)

# 문제의식

### 수작업에 의존하는 자료 분석 방식

방사선 사진 및 임상사진 계측을 육안으로 보고 손으로 직접 탐침을 해야함.

### 진단 분석 시 장소의 제약

프로그램이 설치된 원장실에서만 진단이 가능함.

### 환자수와 무관한 고가의 프로그램

한 명의 환자를 보더라도 프로그램 가격은 수 백 만원 이상

### 환자-치과의사-기공사 원시적 정보전달

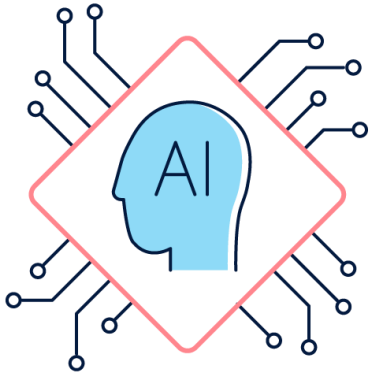
핵심 교정시장의 참여자간 정보 이동의 플랫폼 부재

### 초거대 기공소에 의해 시장 독점화

독보적인 초거대 기업에 의해 투명교정 시장 독점됨. 영세 기공소는 시장 소외.

# 요구 조건

1. 웹 기반 프로그램
2. 인공지능 기술을 사용할 것
3. 사용하기 매우 쉬울 것
4. 환자, 치과의사, 기공사가 참여할 수 있는 플랫폼

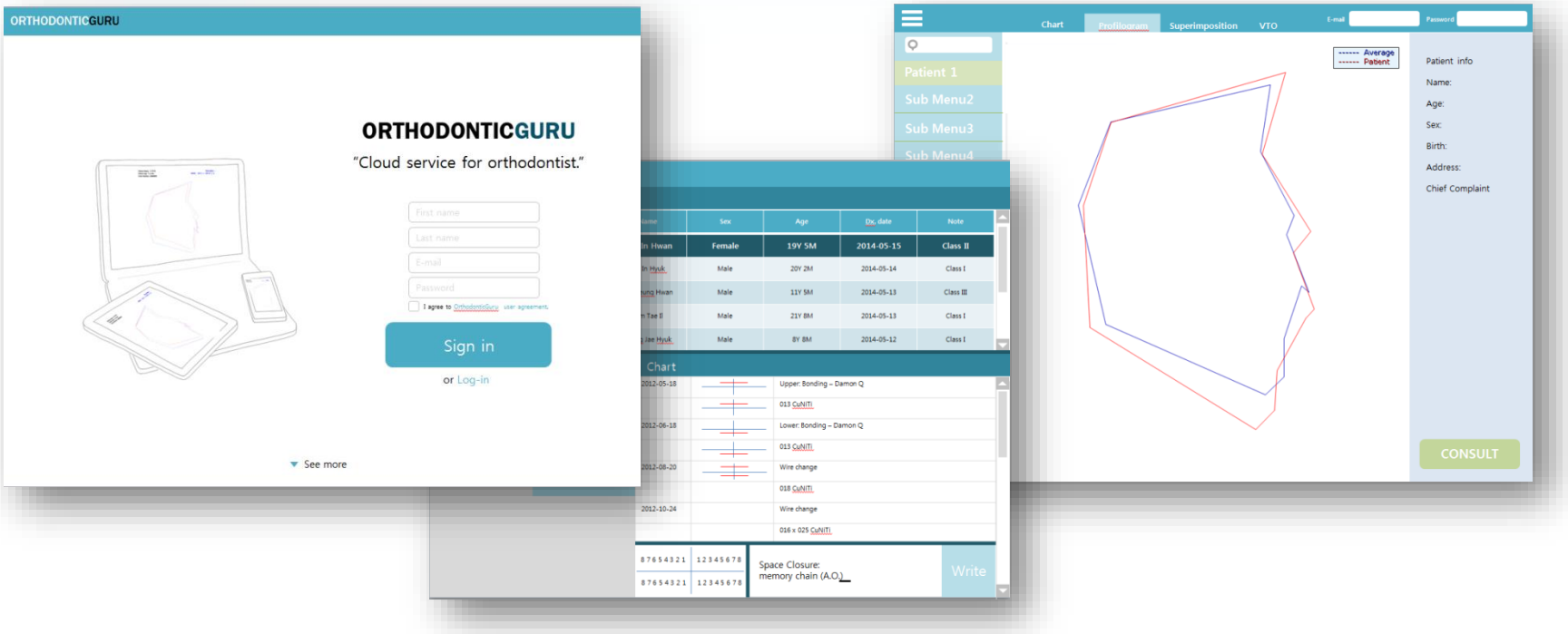



# 개발 스토리

: 덕질의 시작

# 기획자료 및 개발 초안

2014년 4월 (레지던트 2년차) : OrthodonticGuru 기획안 작성



# 프로토타입 개발

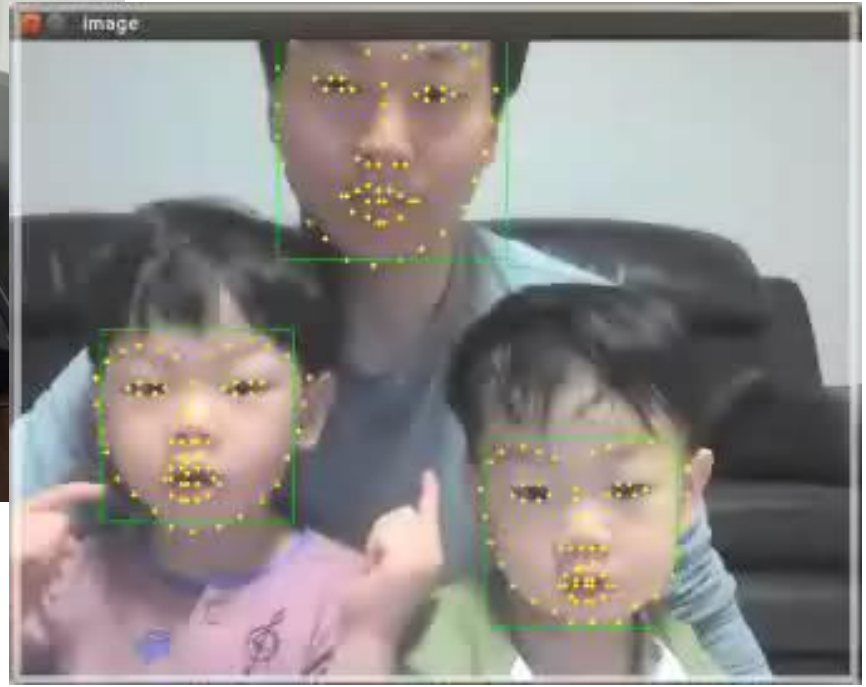
2015년 (레지던트 3년차): WebCeph으로 제품명 확정 후 웹기반 계측프로그램 런칭

# 개발 중단

2016 - 2017년 (펠로우 시절, 개원 초기) : 개발 중단

# Machine Learning 친숙해지려고 시도

2018년 (개원 2년차): Facial Landmark Detection으로 집에서 아들과 가지고 놀기



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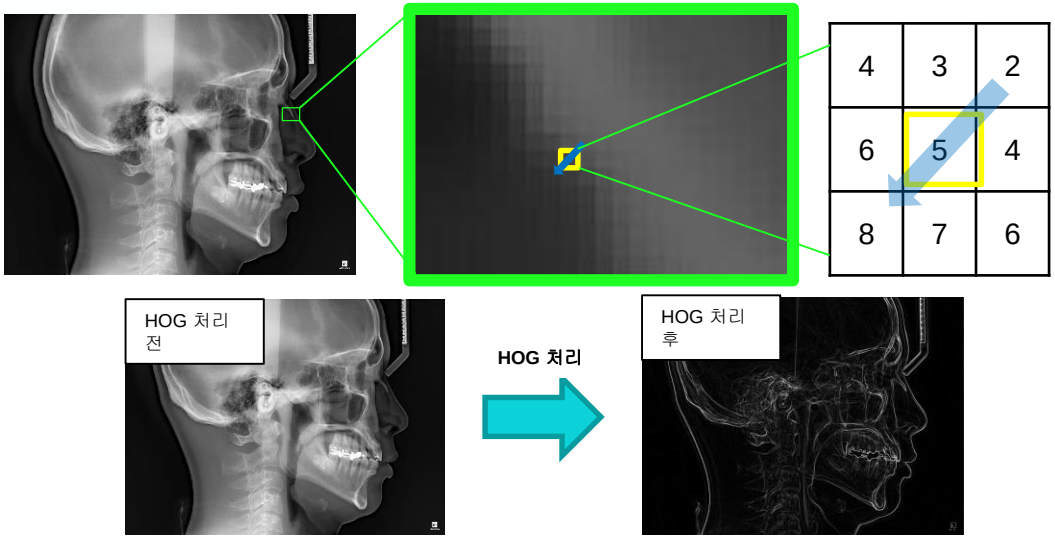

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</image>

<image file='images/00006.jpg'>
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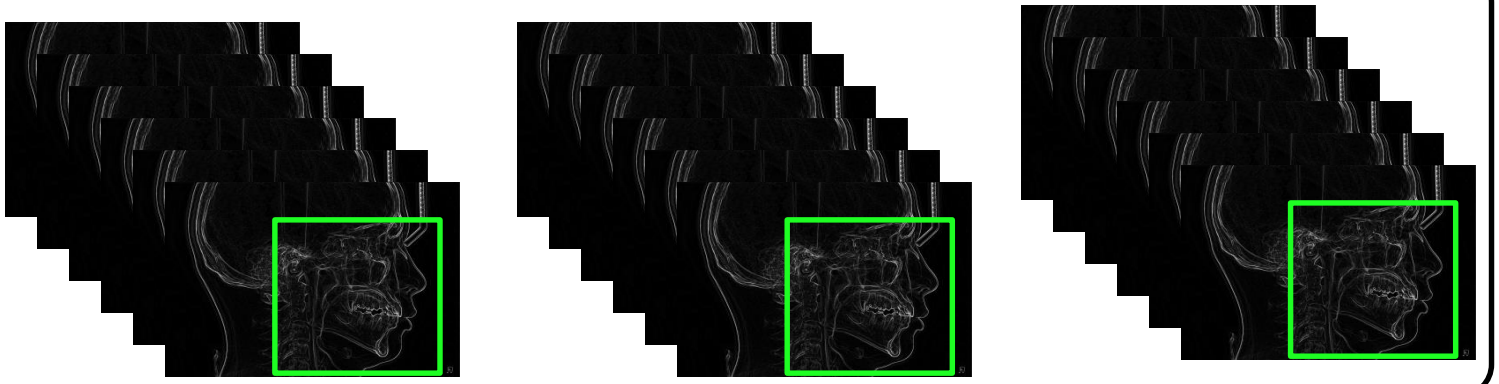
옆얼굴 위치정보와 해부학적 계측정보가 담긴 인공지능 훈련용 데이터



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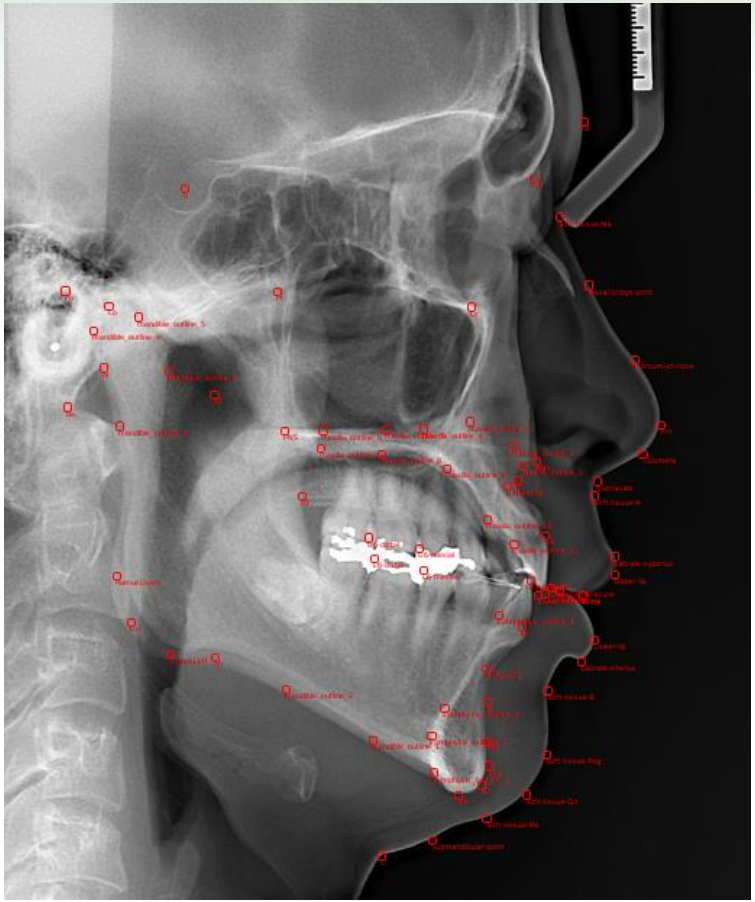

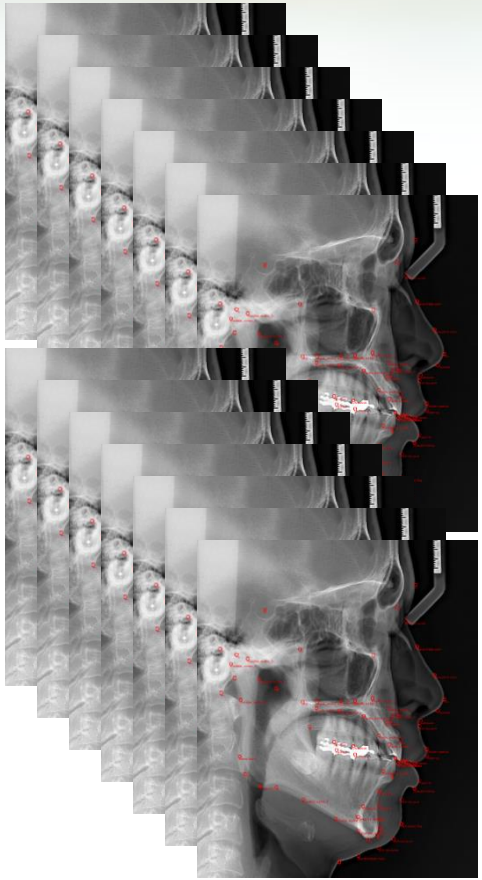

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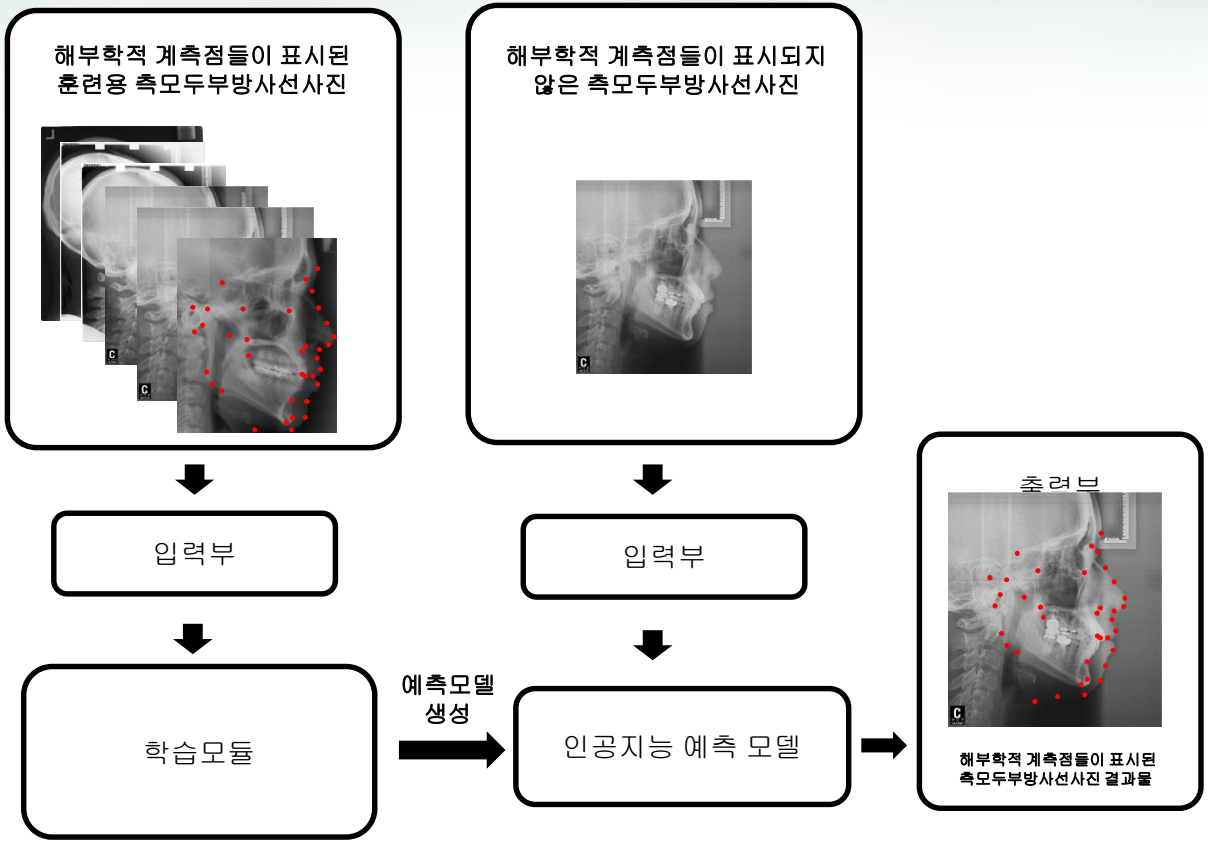
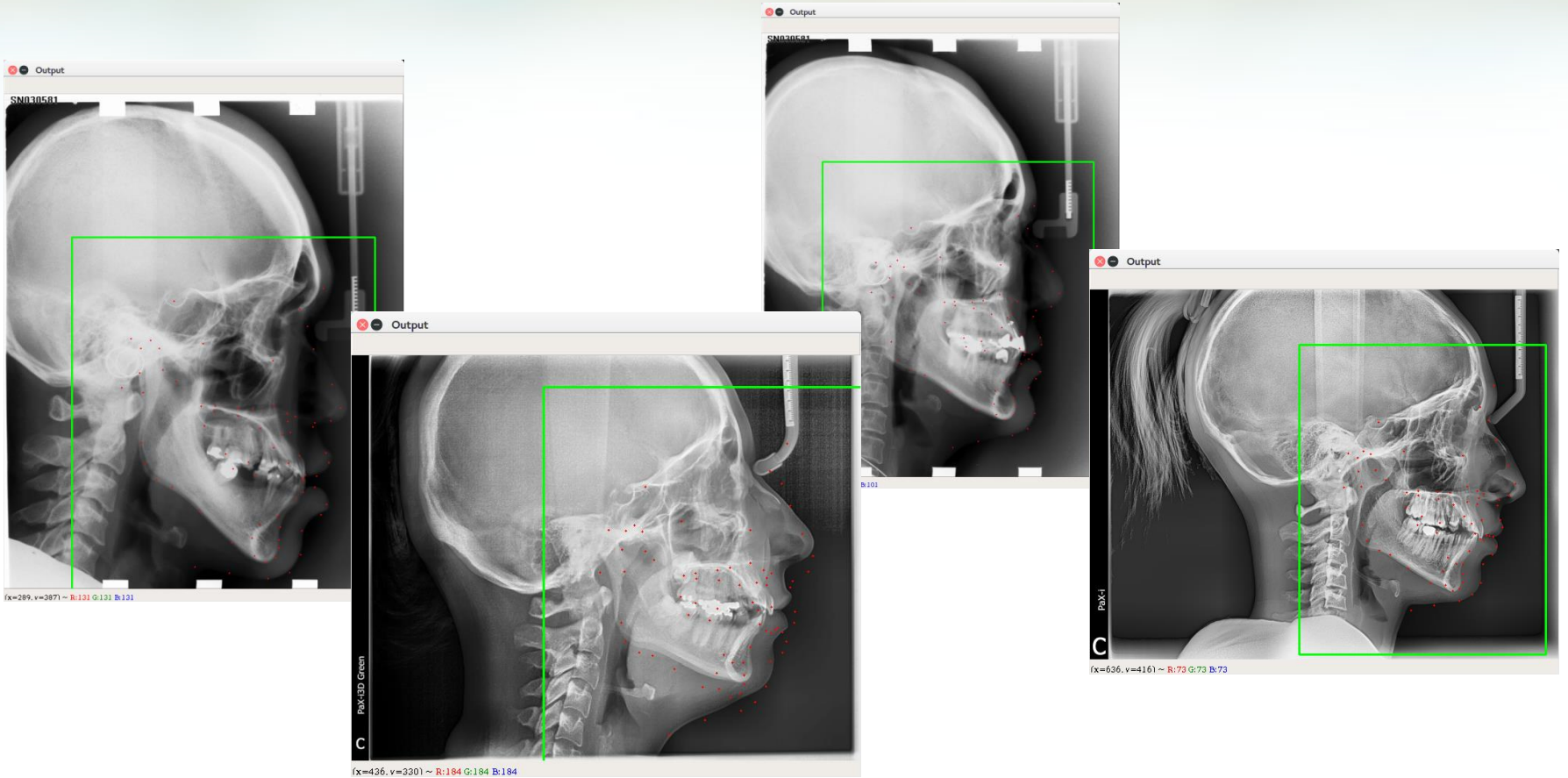


# Machine Learning 결과 테스트



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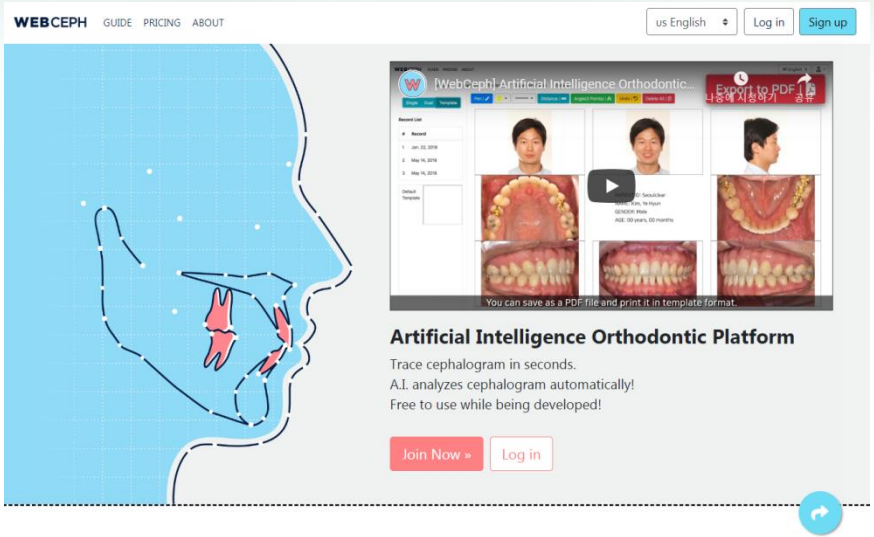
# webceph.com 런칭





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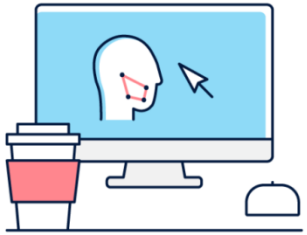

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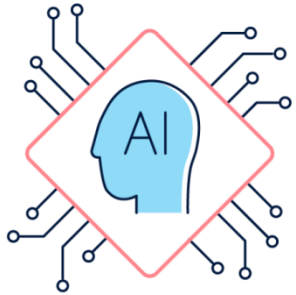
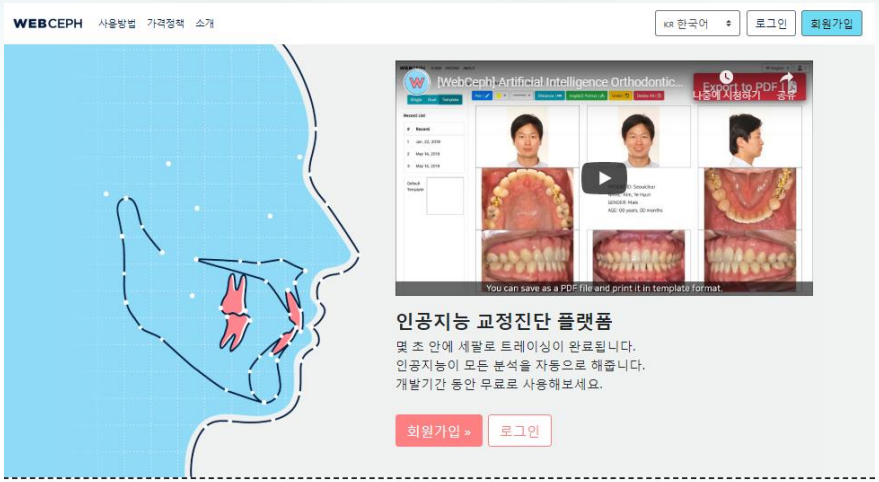


# webceph.com 런칭






## 치료 시뮬레이션 기능

교정 치료결과를 시뮬레이션 할 수 있습니다.
그리고, 악교정수술도 시뮬레이션 가능합니다.
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# 앞으로의 비전

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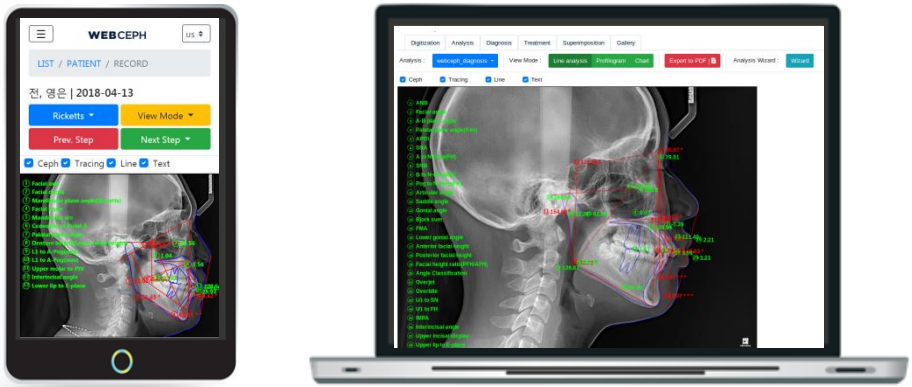

# Thank You!!

경청해주셔서 감사드립니다.

앞으로도 많은 교류를 하길

희망합니다.