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Time series analysis of trends in surgical-orthodontic treatment for Class III patients

III 급 부정교합 수술-교정 치료 추세에 관한 시계열 분석

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- ABSTRACT -

Time series analysis of trends in surgical-orthodontic treatment for Class III patients

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Introduction: Class III patients occupy a significant portion of orthognathic surgery patients. The purpose of this study was to examine the current trends in surgical-orthodontic treatment for Class III patients at Seoul National University Dental Hospital over the past decade using the time series analysis.

Material and methods: From January 1, 2004 through December 31, 2014, records of 2,710 consecutive patients (1,388 women and 1,322 men with an average age of 24 years) who underwent orthognathic surgeries at the Department of Oral and Maxillofacial Surgery, Seoul National University Dental Hospital were reviewed. Investigated variables included patient's gender, age at the time of surgery, malocclusion classification, type of orthognathic surgical procedures, where the orthodontic treatment was performed, orthodontic treatment modality and time elapsed. Using the time series analysis, the trend of Class III surgical management was investigated.

Results: Class III patients occupied approximately 90% among all orthognathic surgery patients. Two-jaw surgeries were performed for 1,831 (82%) patients and became by far the most common type of orthognathic surgical procedures these days. There was no significant difference in the prevalence of gender and age of patients during the past decade. The seasonal variation of age at the time of surgery showed an opposite pattern compared to the number of patients. Increasing trend in the number of Class III orthognathic surgery patients over the years were observed. More than half of the surgery patients received their orthodontic treatment by private practitioners. The proportion of patients who experienced orthodontic treatment with extraction was about 50%. Elapsed time for orthodontic treatment before and after Class III orthognathic surgeries has been decreasing over the years.

Conclusions: Class III malocclusions were predominant among orthognathic surgery patients, and the transition from 1-jaw to 2-jaw surgical procedures for Class III orthognathic patients seemed to be evident over this past decade. The time series analysis demonstrated seasonal variation and trend in this study's demographic and clinical variables. In addition, results of the study might provide clinicians with some insights into surgical and orthodontic management as well as the current spectrum of Class III orthognathic surgery patients.

Key Words: Time series analysis, Class III malocclusion, 2-jaw surgery

Student Number: 2012-22194

국문초록

III 급 부정교합 수술-교정 치료 추세에 관한 시계열 분석

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우리나라에서는 III 급 부정교합 환자들이 턱교정수술을 받는 경우가 가장 많은 편으로 알려져 있다. 이에 본 연구의 목적은 III 급 수술-교정 환자의 특징 및 경시적 변화를 시계열 분석을 이용하여 규명해보는 것이었다.

연구대상은 2004 년 1 월 1 일부터 2014 년 12 월 31 일까지 서울대학교 치과병원 구강악안면외과에서 턱교정수술을 받은 모든 환자 (전체 2710 명, 여자 1388 명, 남자 1322 명, 평균나이 24 세) 였으며, 이들의 의무기록을 조사 하였다. 조사 항목으로는 환자의 부정교합 분류, 성별, 연령, 수술방법, 교정치료 방법 및 치료 기간 등을 포함하여 기록한 후 기술적 분석과 아울러 시계열 분석을 시행하였다.

연구 결과 조사된 모든 턱교정수술환자 중 90%는 III 급 부정교합 환자였으며, 가장 널리 사용되는 턱교정수술방법은 양악수술로 82% 를 차지했고, 10 년 전에 비해 최근으로 갈수록 양악수술의 빈도가 점차 높아지는 추세를 관찰할 수 있었다.

수술 환자들의 경우 외부 병원에서 교정 치료를 받으면서 수술을 위해 의뢰된 경우가 본원에서 교정치료를 받은 환자 보다 약간 더 많은 비중을 차지했다.
성별과 연령에 따른 차이는 유의하지 않았으며, 시계열 분석 결과 수술 건수와 환자의 나이는 서로 상반된 계절적 변이를 보였다.
교정 치료 시 발치와 비발치 빈도는 유의한 차이를 보이지 않았으며, 환자의 교정 치료 기간은 환자 별로 매우 큰 변이를 보였다. 경시적인 변화를 보았을 때, 수술 전 및 수술 후 교정 기간 모두 점차 감소하는 추세를 보였다.

결론적으로 지난 10 년 동안 III 급 수술-교정 치료 환자들의 가장 큰 추세 변화는 수술 사례와 아울러 양악수술이 차지하는 비중이 매우 높아졌다는 것이었으며, 일부 변수의 경우 계절적 변이를 관찰할 수 있었다. 본 연구 결과에서 보고하고 있는 경시적 변화에 대한 시계열 자료는 III 급 수술-교정 환자 진료 시 상담 보조 자료로서 활용될 수 있을 것으로 생각되었다.

주요어 : 시계열 분석, III 급 부정교합, 양악수술

학번 : 2012-22194

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제 III 급 부정교합 수술-교정 치료 추세에 관한 시계열 분석

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-CONTENTS-

I. INTRODUCTION

Orthognathic surgery is the treatment of choice to improve facial esthetics and to correct malocclusion in patients.[1] Combining orthodontic and surgical treatment can provide a more efficient and esthetic treatment.[2] Orthognathic surgery combined with orthodontic treatment has become a common clinical procedure in the correction of dentoskeletal imbalances.

Class III patients are reported to occupy a considerable proportion of orthognathic surgery patients in certain countries.[3-5] Unlike European Americans, Koreans have the highest prevalence of skeletal Class III malocclusion, up to 19% among the general population.[6-8] Correction of skeletal Class III malocclusion is the most frequent reason to seek an orthognathic surgery consultation.[2,4,9,10] Recent popularity on facial esthetics and advances in surgical techniques have resulted in changing trends in the management of severe Class III malocclusion patients.

Limiting the extent of orthognathic surgery may be beneficial for patients. Single jaw surgeries are less invasive and more predictable than 2-jaw surgeries.[2,9] However, for severe Class III patients, 1-jaw surgery alone may be insufficient to achieve a harmonious profile or an optimal occlusion. Therefore, numerous Class III patients require 2-jaw surgery.[10] There have been significant improvements in surgical outcomes and a reduction in morbidity subsequent to orthognathic surgical procedures.[11] For skeletal Class III treatment, the combination of 2-jaw surgery with an additional genioplasty became a common surgical procedure.[10-14] In recent years, an increase in the proportion of 2-jaw surgeries was perceivable at the author's institution also. However, a report using the time series analysis with regard to trends in surgical-orthodontic treatment for Class III patients could not be found yet.

Sophisticated statistical methods may be more informative than that can simply be deduced intuitively. A time series is a sequence of observations that are arranged according to the time of their outcome. The substantial advantage of the time series analysis is the decomposition that eliminates the noise and amplifies the signal within the time series data. Decomposing a time series separates the data into a trend

component and a seasonal component if they exist.[15-17] The time series analysis has been popular in medical field and social science as well. However, as of early October 2015, searching on the website of Pub-Med and Web of Science, only a few papers applied the time series method in dentistry.[18,19] Furthermore, among orthodontic journals, there has yet been no time series article.

The purpose of this study was to examine the current trends in surgical-orthodontic treatment for Class III patients at Seoul National University Dental Hospital over the past decade using the time series analysis.

Specific aims of the study included (1) to identify if there exists a certain seasonal variation and/or trends among the clinical variables examined; (2) if there continues to be a transition from 1-jaw to 2-jaw surgeries, and if so, what might have led to the change.

We hypothesized there has been an increase in 2-jaw surgeries during the past decade. In addition, a recent issue with regard to the 'Surgery First' approach that proposed a reduced extent of orthodontic treatment time was discussed also.

II. MATERIALS AND METHODS

1. Subjects and data collection

This was a retrospective cohort study with regard to all patients who underwent orthognathic surgical procedures at Seoul National University Dental Hospital from 2004-2014. All subjects were of Korean ethnicity. The institutional review board of Seoul National University School of Dentistry for the protection of human subjects reviewed and approved the research protocol (number S-D 20140025).

From January 1, 2004 through December 31, 2014, records of 2,710 consecutive patients (1,388 women and 1,322 men with an average age of 24 years) who underwent orthognathic surgeries at the Department of Oral and Maxillofacial Surgery, Seoul National University Dental Hospital were reviewed. Six different surgeons performed the operations for the patients studied. All patients received pre- and post-surgical orthodontics.

1.1 Excluded patients

Among the patients reviewed, 100 patients who had a diagnosis of cleft lip and palate, craniofacial syndrome, or who had nonconventional orthognathic surgical procedures (eg, osteotomies for distraction osteogenesis, condylar reconstruction) were excluded (**Table 1**).

1.2 Variables investigated

To investigate the trend changes of Class III surgical management, demographic variables and clinical variables were reviewed and classified.

Continuous variables were the age at the time of surgery, pre- and post-surgical orthodontic treatment time. For the 1,035 patients whose orthodontic treatments were performed by the orthodontists at the same institution, their records were fully accessible. We examined the treatment time of orthodontic treatment both for before- and after their orthognathic surgeries.

The pre-surgical orthodontic treatment time was defined as the time elapsed from placement of the first

active orthodontic component to the day that final planning impressions were taken and the patient was ready for operation.

The post-surgical orthodontic treatment time was calculated the duration from the date of surgery and at the time of debonding/debanding.

Multiple categorical and/or dichotomous variables included the followings.
Gender of the patients;
Angles Classification;
Type of orthognathic surgery, i.e., 1-jaw versus 2-jaw surgery;
Conjunctive surgical procedures such as genioplasty or para-nasal augmentation performed;
Place of supportive orthodontic treatment, i.e., at private office versus department of orthodontics at the same institution, Seoul National University Dental Hospital;
Orthodontic treatment with the upper premolar extraction versus non-extraction.

2. Statistical data analysis

After checking the basic assumption for the normality and the equality of variance, the *t*-test was performed to compare the age difference between female and male patients. The chi square test or the Fisher Exact test was applied to compare the distribution of the categorical variables.

The time series analysis was performed using the free statistics software language R (R Development Core Team, Vienna, Austria).[17] To make future forecasts, the additive Holt-Winters prediction function was applied. This is an exponential smoothing method in forecasting trends and seasonal variations by exponentially weighted moving averages.[15] Detailed program codes are described in the appendix section.

A *p*-value of less than 0.05 was considered statistically significant.

III. RESULTS

1. All of the orthognathic surgery patients reviewed

From 2004 to 2014, a total of 2,710 patients received orthognathic surgical procedures at the Department of Oral and Maxillofacial Surgery, Seoul National University Dental Hospital.

There was no statistically significant difference in the prevalence of gender and age of patients. About a half of the patients were transferred patients from private orthodontic offices where pre- and postsurgical orthodontic treatments were performed (**Table 1**).

Among them, 2,240 patients were Class III patients. This was approximately 90% of orthognathic surgeries performed after excluding patients having cleft lip and palate and other anomalies. Patients who had Class III malocclusion (n = 2,240, 89%) were much outnumbered Class I (n = 134, 5%) and Class II patients (n = 236, 9%)

Over the past decade, the dominant proportion of Class III malocclusion among surgery patients has not been changed over time (**Figure 1**).

2. Number of Class III orthognathic surgery patients and forecasting the near future

The result of the time series analysis demonstrated a clear seasonal variation and an increasing trend in the number of Class III orthognathic surgery patients over the years.

Figure 2 demonstrated that there seems to be seasonal variation in the number of Class III surgery patients (**Figure 2**, *top*).

There were peaks in every winter and summer. Peaks in winter were higher than those appeared in summer (**Figure 2**, *second from top*). The magnified view of the seasonal variation indicated that the

number of patients increased both in summer and winter breaks at schools in Korea (**Figure 2**, *bottom*).

The trend component showed that the number of patients seemed to have decreased from about 2006 to about 2009, followed by a steady increase from then on to 2013 and then a small decrease from about 2013 was observed (**Figure 2**, *third from top* in).

However, it appeared that an additive model was not appropriate for describing the time series, since the size of the seasonal fluctuations and random fluctuation seemed to increase over time. Thus, to get a transformed time series described using an additive model, log transformation was performed. In the log-transformed time series, the size of the seasonal fluctuations and random fluctuations seemed to be roughly constant over time, and do not depend on the level of the time series (**Figure 3**, *top*). To predict future number of patients, first, the time series dataset was seasonally adjusted by estimating the seasonal component, and subtracting the estimated seasonal component from the original dataset.
The forecasts for 2015 – 2016 were depicted (**Figure 3**, *bottom*) as a solid blue line, the 80% prediction interval as a light blue shaded area, and the 95% prediction interval as a grey shaded area, which should be re-evaluated in the future.

3. Female vs. male patients

There was no significantly different proportion between female and male patients. The proportion of female over male patients was approximately 1/2 and has not changed substantially over time.

The time series graphics did not show an obvious seasonal variation nor clear trend (**Table 2; Figure 4**).

4. Age at the time of surgery

The mean age at the time of orthognathic surgery was 23.3 years and did not differ between female and male patients (**Table 2**).

However, the time series analysis demonstrated a distinct seasonal variation of the age at the time of Class III orthognathic surgery. A large scale view of the seasonal variation showed an opposite pattern compared to the number of patients. During the vacation seasons, the patients were younger than other times of a year students (**Figure 5**). Probably, they seemed to be college students who wanted to receive their surgical procedures taking advantage of the long school off-days.

5. Place of supportive orthodontic treatment

Patients who received orthodontic treatment at private offices were more than 50%, which did not have changed over time (**Figure 6**). Orthodontic treatments for approximately 54% of the patients were performed at private offices and were transferred to this institution for their orthognathic surgery. The rest of the patients, 46% received orthodontic treatment by the faculty or residents at the Department of Orthodontics, Seoul National University Dental Hospital (**Table 2**).

Comparisons between the Class III surgery patients who received their orthodontic treatment at the Department of Orthodontics, Seoul National University Dental Hospital and by private practitioners did not show a significantly different proportion either in gender, type of orthognathic surgery, or orthodontic treatment modality (**Table 3**).

6. Orthodontic treatment modality

The proportion of patients who experienced orthodontic treatment with extraction was about 50% (**Tables 2 and 3**).

The time series graphics did not show an obvious seasonal variation and clear trend either (**Figure 7**).

7. Type of orthognathic surgery

Two-jaw surgeries were performed for 1,831 (82%) patients and by far the most common type of orthognathic surgical procedures. An increase in 2-jaw surgeries and a concurrent reduction in 1-jaw surgeries were noted in recent years. Since 2010 the percentage went up about 90% (**Table 2; Figure 8**).

Comparison between the 1-jaw and 2-jaw surgery patients, there was no significant difference in the reviewed patient characteristics including patient's sex, age, and the proportion of extraction orthodontic treatment (**Table 4**).

After the time series analysis, the trend component demonstrated that the spectrum of surgical procedures for Class III patients has changed from 1-jaw to 2-jaw orthognathic surgeries over the past decade (**Figure 8**).

For mandibular setback, procedures commonly carried out were BSSRO s in 1,904 (85%) of patients among them, followed by IVSRO (in 13% of patients). Among the maxillary surgical procedures, the Le Fort I osteotomy was the most frequent in 1,816 (81%) of patients (**Tables 2 and 5**).

Additional surgeries included various procedures. Genioplasty was most commonly performed in 1,091 (49%) of patients. Although the incidence was not high, anterior segmental osteotomy in the maxilla and/or in the mandible, paranasal augmentation, and zygoma reduction were performed in some patients (**Table 5**).

8. Pre- and post-surgical orthodontic treatment time

The time elapsed for the pre- and post-surgical orthodontic treatment was highly variable for each individual Class III orthognathic surgery patient as depicted in **Figure 9**.

Histograms were depicted to visualize the distribution of patient's age at the time of surgery, pre-operative, post-operative, and the total orthodontic treatment time. After plotting histograms, all of the time related continuous variables demonstrated skewed distribution. When compared to the normal curve, the histograms looked skewed heavily towards the right. The long tails on the right side indicated there existed several patients who were older than others were or received longer treatment than usual (**Figure 10**).

To get the distribution normalized that can be handled by parametric statistical inference, variance stabilizing transformation methods were applied including logarithmic, square root, and square root of the square root transformation. However, none of the data transformation methods was successful in obtaining normal Gaussian distribution (transformed data not shown).

Prior to surgery, the median duration of surgical preparation was 13.4 months (mean, 14.7 months) and the median time for the finalization of orthodontic treatment after surgery was 8.7 months (mean, 10.2 months) In case of extraction treatment modality the duration for the pre- and postoperative orthodontic treatments were extended significantly. Collectively, the median time for orthodontic treatment was slightly less than 2 years (23.4 months). This was not significantly different between genders or between 1-jaw and 2-jaw surgeries (**Table 6**).

The results of the time series analysis demonstrated that times required for orthodontic treatment before and after Class III orthognathic surgeries have been decreasing over the years (**Figure 11**).

IV. DISCUSSION

As far as previous publications were searched, this seemed to be the first attempt to examine the current trends in surgical-orthodontic management using the time series analysis. The tables 1 – 5 demonstrated conventional and typical style of results presentation in this study. However, since the data set should primarily deal with time related characteristics, the time series analysis and its graphic visualization would be more informative and easier to understand than multiple tables. In addition, through decomposition, meaningful signals from noise can be extracted by the time series analysis,[15,17] without which the today's surgical trend into 2-jaw surgeries from the 1-jaw surgery in the past and seasonal variation in the number of patients and age at the time of surgery could not be confirmed.

This study's result showed that Class III patients were predominant. On the contrary, the high proportion of patients with Class II among the Westerners are comparable to this overwhelming Class III patients in Koreans.[20] The highest prevalence of Class III orthognathic surgical procedures, a roughly 90% among all orthognathic surgery patients reviewed was in fact expected, which seemed to be consistent with the previous reports regarding the frequent skeletal Class III malocclusions management and treatment in my society.[2,4,9,21] First, this may be because the general population in Korea was known to have the highest prevalence of Class III malocclusion worldwide, up to approximately 1/5.[6-8] Therefore, Class III surgery patients were expected to have a larger portion of patients experiencing orthognathic surgeries than other malocclusion groups, and the present data indicated that they did. Second, this finding may suggest that Class III feature is relatively unacceptable within the population and prompts many patients to seek surgical intervention. Several studies showed that Class III patients might be much more inclined to opt for surgical treatment than Class II patients who might hope to receive compensatory orthodontic treatment.[5,8]

Over this past decade, the transition from 1-jaw to 2-jaw surgical procedures for Class III orthognathic patients looked evident. Two-jaw surgeries with mandibular setback (98%) and concomitant maxillary osteotomy (82%) were by far the most common type of surgical procedures. The result on an average

indicated 82% of 2-jaw surgeries. However, in recent years, an increase in the proportion of 2-jaw surgeries were substantial. Especially since 2010, the percentage went up about 90%. As far as the patient characteristics reviewed so far, for example patient's sex, age, and the proportion of extraction orthodontic treatment, there was no significant difference between the 1-jaw and 2-jaw surgery patients. It is understandable that 2-jaw surgeries can produce a better profile and occlusion than simple 1-jaw surgeries. It is also true that Koreans' Class III are different from those of Westerners in that the skeletal components usually involved maxillary deficiency.[22] In addition, the use of mandibular setback surgery alone in treating a Class III profile might probably cause numerous disadvantages including sleep apnea.[1,23,24] Two-jaw surgeries became a common and safe procedure today.[11] Also in the US, 2-jaw surgeries seemed to be the current trend.[11-14] Having considered the advantageous features of 2-jaw surgeries, nevertheless, the current trend toward about 90% of 2-jaw surgeries looked excessively high. May it be due to the surgeon's willingness to perform 2-jaw surgeries? The present study could not fully answer this question.

The background for the predominance of 2-jaw approaches for correction of skeletal Class III might be conjectured with several probable causes.

First, it may be due to the fact that this investigation was performed in an academic center. One might expect 2-jaw surgery patients concentrated in academic centers because of the complexity of the surgery. The high incidence of 2-jaw surgeries may reflect the greater severity of dentofacial deformities seen in university dental hospital.[11] This study could not investigate cephalometric variables for 2,240 patients. However, as far as the patient characteristics reviewed so far, there was no significant difference between the 1-jaw and 2-jaw surgery patients.

Second, it may be a possibility that 2-jaw surgery patients have moved from the private practice surgeons to academic oral surgeons at university hospitals. However, a shift of 2-jaw surgery patients from private practitioners to university surgeons is unlikely to explain this apparent increased incidence in 2-jaw surgeries at this institution.

Third, socio-economic changes could be cited as a background. A report from the US discussed that in the university setting, surgeons are salaried and a portion of their compensation is salary based.[11]

However, this might be not true in our society or in my institution at least. In addition, unlike in the US, orthognathic procedures are not being covered by medical/dental insurance policy but simply have relied on pocket expenses by the patients and their parents. The socio-economic development in my society might have affected the high acceptance of 2-jaw surgical procedures by the patients that demanded more monetary expenses more than 1-jaw surgeries did.

Orthodontists would understand the trends toward 2-jaw orthognathic procedures by oral surgeons would be a natural and inescapable one. They should be grateful for the excellent surgeons and clinical advances in orthognathic surgery. At the same time, no matter either of the causes might have influenced the trends toward 2-jaw surgeries so far, there are worrisome implications associated with the finding of extreme prevalence of 2-jaw surgeries. Will there be possible alternatives? It might be desirable if the complexity of the surgery could be minimized through effective pre- and postsurgical orthodontic treatment. A concerted effort could be made by surgeons and orthodontists to avoid 2-jaw surgeries with current advances in orthodontic biomechanics and treatment prediction.[2,9-11,25-27]

The patients in this investigation did not show different portion between female and male patients. Over this past decade, the number of male patients was much the same as the female patients, which was the similar result to previous reports in the US, 2014[1] and in Singapore, 2006.[3] Meanwhile, a 2014 report in Brazil demonstrated females were more prevalent among orthognathic surgery patients in 6:4.[5]

In this study, the number of surgery patients did not decrease over time. However, in the US, the situation seemed to be different. For example, a 2014 report from the University of Pennsylvania, Philadelphia,[28] a 2005 article from Cleveland, Ohio,[14] and a national survey in 2008[11] found in common that past 2 decades there has been a decrease in the number of orthognathic surgery patients. Most oral and plastic surgeons and orthodontist in the US claimed that the reimbursement was the major reason for the reduction in the number of surgical procedures. The decline was attributed mainly to the significant reduction in reimbursement by insurance providers.[11,28] Advances in orthodontic techniques such as orthodontic mini-implants and mini-plates would have reduced the necessity of orthognathic surgical procedures.[2,27,29,30]

A report from the plastic surgeons perspective provided an additional cause for the decline of orthognathic surgery patients in the US. It was caused by orthodontists and oral surgeons. According to the medical surgeon's viewpoint, referral patterns for orthognathic surgery patients have also changed over the years. Among the surgery patients, the orthodontists running private practice refers their patients more over the years. The discussion continued to that 'it appears that oral surgeons are performing the majority of orthognathic surgery in the United States today. This loss of plastic surgeon case volume mirrors similar trends in both hand and head and neck cancer surgery.'[11]

Another different feature from the US statistics included that more than half the patients (54%) seeking an orthognathic surgery consultation in the University of North Carolina Dentofacial Clinic were Class II patients and 3/4 of these classified with mandibular deficiency. Whereas Class III occupied only 30% among the patients in North Carolina.[20] In Brazil, Class III surgery patients were predominant, 55%,[5] and in Singapore, the percentage reached up to 68%.[3]

Another important factor evaluated in this study was the time durations elapsed during the pre- and post-surgical orthodontic treatment. Although orthodontists could primarily affect the time duration, further investigation will be necessary as time elapsed may merely reflect variation in other factors such as treatment severity and patient's compliance.

The shortened time and/or reduced extent of supportive orthodontic treatment for the patients might be related with the transition to 2-jaw surgeries. For example, the shorter length of pre-surgical orthodontic treatment or non-extraction treatment modality might have been related with the increasing tendency of taking 2-jaw surgeries, which could not be found in this study.

Meanwhile **Table 5** could be used as a communication tool with patients before commencing the treatment. It might be applied to have patients informed that the total treatment time may last longer than 2 years and 2 months for extraction patients, or less than 20 months otherwise.

As shown in **Figures 9 and 10** orthodontic treatment time varied significantly each patient. In reality, all of the time related variables show skewed distribution in nature. The long tails on the right sides indicated there existed a few patients who were older than others and/or several patients received longer

orthodontic treatment than usual. In fact, it is common that time and currency variables as well are subjected to be skewed. In this study, various kinds of variance stabilizing transformation methods were applied but to no effect. This was suggestive of the impossibility in handling the time related variables with a simple parametric statistical inference.

In clinical practice, it is a possibility that a few patients could experience unexpectedly long period of orthodontic treatment for some reason. In **Figures 9**, the long and outstanding line spikes viewed as outliers that presented in the long right-hand sided tails of the histograms demonstrated **Figure 10**. From the clinical point of view, the skewed distribution of all of the time related variables might reflect the real clinical situation. Numerically, the skewed non-Gaussian distribution resulted in the disparity between the mean and median values (**Table 6**). In this situation, when comparing the treatment time of patients, careful inferential technique seemed to be necessary taking the seasonal and trend variation into account. Instead, the non-normal distribution and variation over time should be taken into account. To restate, simple parametric inferential tests such as *t* test and ANOVA may not be an appropriate way of analysis. The time series analysis could be a better method to handle the for the time related variables.

After applying the time series analysis, decreasing patterns of presurgical, postsurgical and thereby total orthodontic treatment times have been observed (**Figure 11**). Advances in surgical procedures and improvement of stability after surgery as well as effective orthodontic treatment mechanics would have shortened the time required. We would also like to discuss namely the 'Surgery First' approach that proposed a reduced extent of pre-surgical orthodontic treatment. It was supposed to be a new concept and to have shorter treatment time.[31-37] However, as far as the author remembers, before 1980's, most surgeons did not want to have orthodontists perform pre-surgical orthodontic treatment. From the beginning, orthognathic surgeries were 'Surgery First' approach. It would be practically impossible to measure the quality of the treatment results from the 'Surgery First' approach. However, one thing for sure is that it may well raise a question about statistical analysis issues on the papers published by the advocates for 'Surgery First'. They have been showing a significantly shorter orthodontic treatment. However, most studies regarding the 'Surgery First' approach had a limited number of subjects. In

addition, they have not applied the time series analysis for taking the decreasing trends of orthodontic treatment time into account. Not to mention, considering the skewed distribution of the time variables, the comparison would have been more appropriate with non-parametric data analysis.

The present study also has several limitations. Ethnic influence could not be measured because of limited ethnicity, all Korean. In addition, no conclusion could be drawn on how many Class III patients are in need of and will be benefited from orthognathic surgeries in the population at large. In reality, it may be also true that academic surgeons constitute a relatively small percentage of oral and maxillofacial surgeons nationally, however, they might perform a significant proportion of the total number of orthognathic surgeries.[11]

Although all of 2,710 orthognathic patients were investigated, the subjects were collected in a limited time span of 2004 – 2014 and in a limited space only at an academic institution located in downtown Seoul, Korea. It may be informative if this type of time series analysis may be performed in the future again. Further expansion of the subjects will be more desirable with multicenter, multi-ethnicity design that can provide with a large number of subjects.

V. CONCLUSIONS

This was a retrospective cohort study of all patients who underwent orthognathic surgical procedures at Seoul National University Dental Hospital from 2004-2014. In this study, using the time series analysis the current trends of Class III orthognathic surgery patients were investigated over this past decade. This might allow some insights into the spectrum and management of Class III surgery patients. The major results were as follows.

1. The spectrum of surgical-orthodontic treatment for Class III patients has changed from 1-jaw to 2-jaw orthognathic surgeries over the past decade.
2. The number of patients and age at the time of surgery demonstrated seasonal variation.
3. The time duration of orthodontic treatment for surgery patients has been decreasing over time.

VI. REFERENCES

1. Peacock ZS, Lee CC, Klein KP, Kaban LB. Orthognathic surgery in patients over 40 years of age: indications and special considerations. J Oral Maxillofac Surg 2014;72:1995-2004.
2. Suh HY, Lee SJ, Park HS. Use of mini-implants to avoid maxillary surgery for Class III mandibular prognathic patient: a long-term post-retention case. Korean J Orthod 2014;44:342-349.
3. Chew MT. Spectrum and management of dentofacial deformities in a multiethnic Asian population. Angle Orthod 2006;76:806-809.
4. Jung MH. Age, extraction rate and jaw surgery rate in Korean orthodontic clinics and small dental hospitals. Korean J Orthod 2012;42:80-86.
5. Sato FR, Mannarino FS, Asprino L, de Moraes M. Prevalence and treatment of dentofacial deformities on a multiethnic population: a retrospective study. Oral Maxillofac Surg 2014;18:173-179.
6. Lee SJ, Kim TW, Suhr CH. Recognition of malocclusion and orthodontic treatment. Korean J Orthod 1994;24:193-198.
7. Lee YS, Lee SJ, An H, Donatelli RE, Kim SH. Do Class III patients have a different growth spurt than the general population? Am J Orthod Dentofacial Orthop 2012;142:679-689.
8. Kim JY, Lee SJ, Kim TW, Nahm DS, Chang YI. Classification of the skeletal variation in normal occlusion. Angle Orthod 2005;75:311-319.
9. Suh HY, Lee SJ, Lee YS, Donatelli RE, Wheeler TT, Kim SH et al. A more accurate method of predicting soft tissue changes after mandibular setback surgery. J Oral Maxillofac Surg 2012;70:e553-562.
10. Lee YS, Suh HY, Lee SJ, Donatelli RE. A more accurate soft-tissue prediction model for Class III 2-jaw surgeries. Am J Orthod Dentofacial Orthop 2014;146:724-733.
11. Zins JE, Morrison CM, Gonzalez AM, Altus GD, Bena J. Follow-up: orthognathic surgery. Is there a future? A national survey. Plast Reconstr Surg 2008;122:555-562.
12. Johnston C, Burden D, Kennedy D, Harradine N, Stevenson M. Class III surgical-orthodontic treatment: a cephalometric study. Am J Orthod Dentofacial Orthop 2006;130:300-309.
13. Bailey LJ, Cevidanes LH, Proffit WR. Stability and predictability of orthognathic surgery. Am J Orthod Dentofacial Orthop 2004;126:273-277.
14. Zins JE, Bruno J, Moreira-Gonzalez A, Bena J. Orthognathic surgery: is there a future? Plast Reconstr Surg 2005;116:1442-1450.
15. Coghlan A. A Little Book of R For Time Series Release 0.2. Available at: https://media.readthedocs.org/pdf/a-little-book-of-r-for-timeseries/latest/a-little-book-of-r-for-time-series.pdf. Accessed October 7, 2015.; 2015.
16. Brockwell PJ, Davis RA. Introduction to Time Series and Forecasting. Springer; 2002.
17. R Development Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2015.
18. Swedberg Y, Noren JG. A time-series analysis of caries status among adolescents in relation to socioeconomic variables in Goteborg, Sweden. Acta Odontol Scand 1999;57:28-34.
19. Kozelj V, Vegnuti M. Time series analysis of births of children with orofacial clefts. J Craniomaxillofac Surg 2000;28:201-203.
20. Severt TR, Proffit WR. The prevalence of facial asymmetry in the dentofacial deformities population

at the University of North Carolina. Int J Adult Orthodon Orthognath Surg 1997;12:171-176.
21. Lee SJ, Kim TW, Nahm DS. Transverse implications of maxillary premolar extraction in Class III presurgical orthodontic treatment. Am J Orthod Dentofacial Orthop 2006;129:740-748.
22. Ellis E, 3rd, McNamara JA, Jr. Components of adult Class III malocclusion. J Oral Maxillofac Surg 1984;42:295-305.
23. Boyd SB, Walters AS, Song Y, Wang L. Comparative effectiveness of maxillomandibular advancement and uvulopalatopharyngoplasty for the treatment of moderate to severe obstructive sleep apnea. J Oral Maxillofac Surg 2013;71:743-751.
24. Hsieh YJ, Liao YF. Effects of maxillomandibular advancement on the upper airway and surrounding structures in patients with obstructive sleep apnoea: a systematic review. Br J Oral Maxillofac Surg 2013;51:834-840.
25. Yoon KS, Lee HJ, Lee SJ, Donatelli RE. Testing a better method of predicting postsurgery soft tissue response in Class II patients: A prospective study and validity assessment. Angle Orthod 2015;85:597-603.
26. Donatelli RE, Lee SJ. How to test validity in orthodontic research: a mixed dentition analysis example. Am J Orthod Dentofacial Orthop 2015;147:272-279.
27. Cousley RR, Turner MJ. Mini-implant applications in orthognathic surgical treatment. J Orthod 2014;41 Suppl 1:s54-61.
28. Ford B. Trends in Orthognathic Surgery: A National Survey of Orthodontists 2014 Annual Meeting: AAOMS; 2014.
29. Lee SJ, Ahn SJ, Lee JW, Kim SH, Kim TW. Survival analysis of orthodontic mini-implants. Am J Orthod Dentofacial Orthop 2010;137:194-199.
30. Lee SJ, Lin L, Kim SH, Chung KR, Donatelli RE. Survival analysis of a miniplate and tube device designed to provide skeletal anchorage. Am J Orthod Dentofacial Orthop 2013;144:349-356.
31. Huang CS, Hsu SS, Chen YR. Systematic review of the surgery-first approach in orthognathic surgery. Biomed J 2014;37:184-190.
32. Hernandez-Alfaro F, Guijarro-Martinez R, Peiro-Guijarro MA. Surgery first in orthognathic surgery: what have we learned? A comprehensive workflow based on 45 consecutive cases. J Oral Maxillofac Surg 2014;72:376-390.
33. Min BK, Choi JY, Baek SH. Comparison of treatment duration between conventional three-stage method and surgery-first approach in patients with skeletal Class III malocclusion. J Craniofac Surg 2014;25:1752-1756.
34. Ko EW, Hsu SS, Hsieh HY, Wang YC, Huang CS, Chen YR. Comparison of progressive cephalometric changes and postsurgical stability of skeletal Class III correction with and without presurgical orthodontic treatment. J Oral Maxillofac Surg 2011;69:1469-1477.
35. Baek SH, Ahn HW, Kwon YH, Choi JY. Surgery-first approach in skeletal class III malocclusion treated with 2-jaw surgery: evaluation of surgical movement and postoperative orthodontic treatment. J Craniofac Surg 2010;21:332-338.
36. Kim JY, Jung HD, Kim SY, Park HS, Jung YS. Postoperative stability for surgery-first approach using intraoral vertical ramus osteotomy: 12 month follow-up. Br J Oral Maxillofac Surg 2014;52:539-544.
37. Lee NK, Kim YK, Yun PY, Kim JW. Evaluation of post-surgical relapse after mandibular setback surgery with minimal orthodontic preparation. J Craniomaxillofac Surg 2013;41:47-51.

FIGURES

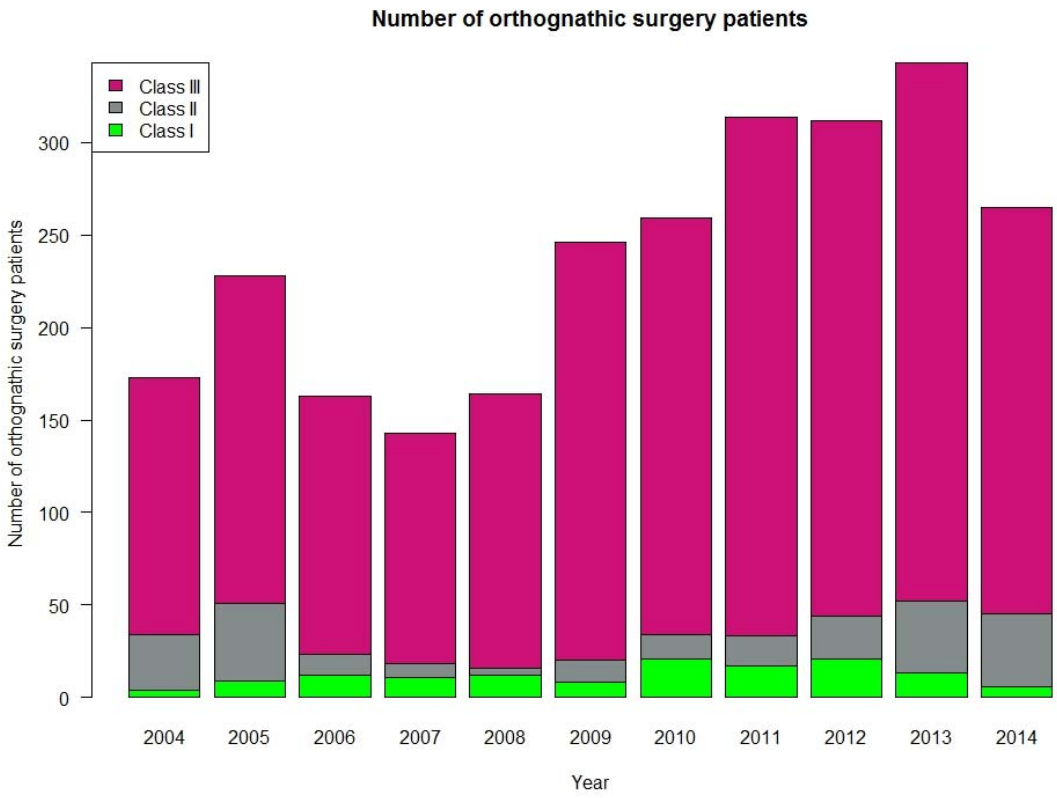

Figure 1. Over the past decade from 2004 to 2014, most of the patients seeking orthognathic surgeries at the Department of Oral and Maxillofacial Surgery, Seoul National University Hospital were Class III patients. The dominant proportion of Class III patients has not been changed over time.

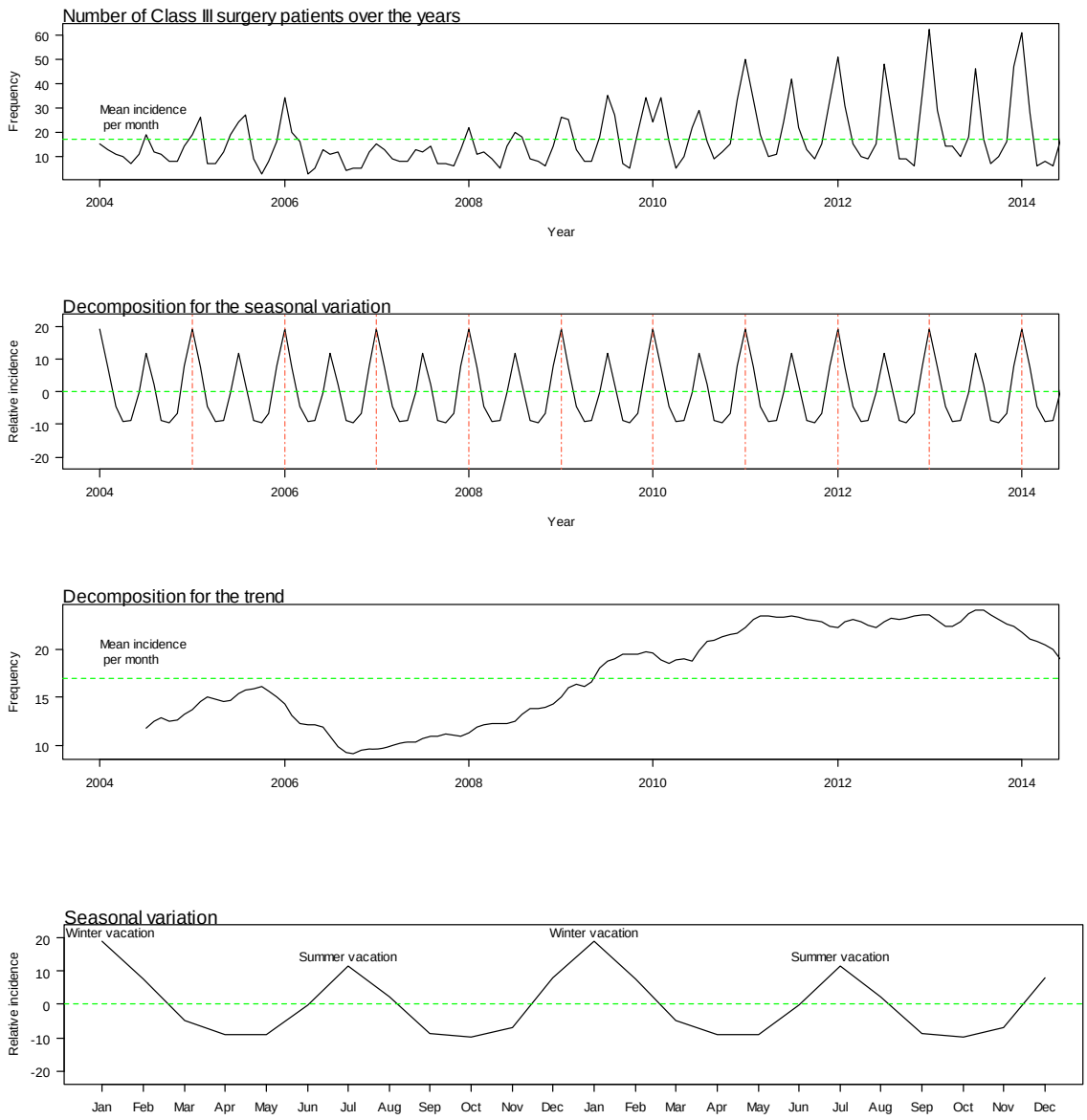

Figure 2. Over the past decade from 2004 to 2014, the time series analysis demonstrated a clear seasonal variation and a roughly increasing trend in the number of Class III orthognathic surgery patients. At the bottom of the multi-frame graphics, the magnified view of the seasonal variation indicated that the number of patients increased both in the summer and winter breaks at schools in Korea.

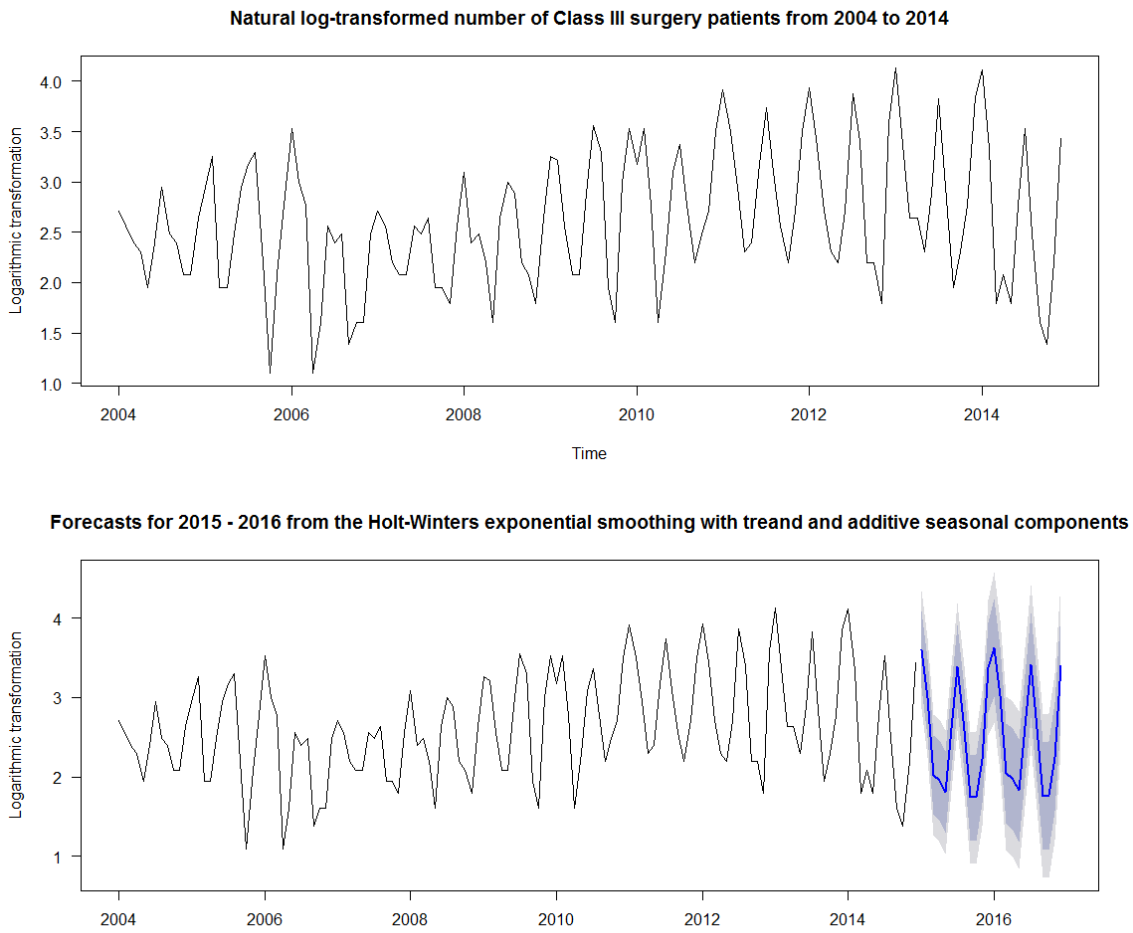

Figure 3. In the log-transformed time series, the size of the size of the seasonal fluctuations and random fluctuations seemed to be roughly constant over time, and do not depend on the level of the time series (*top*). The forecasts for 2015 – 2016 were depicted as a solid blue line, the 80% prediction interval as a light blue shaded area, and the 95% prediction interval as a grey shaded area, which should be re-evaluated in the future (*bottom*).

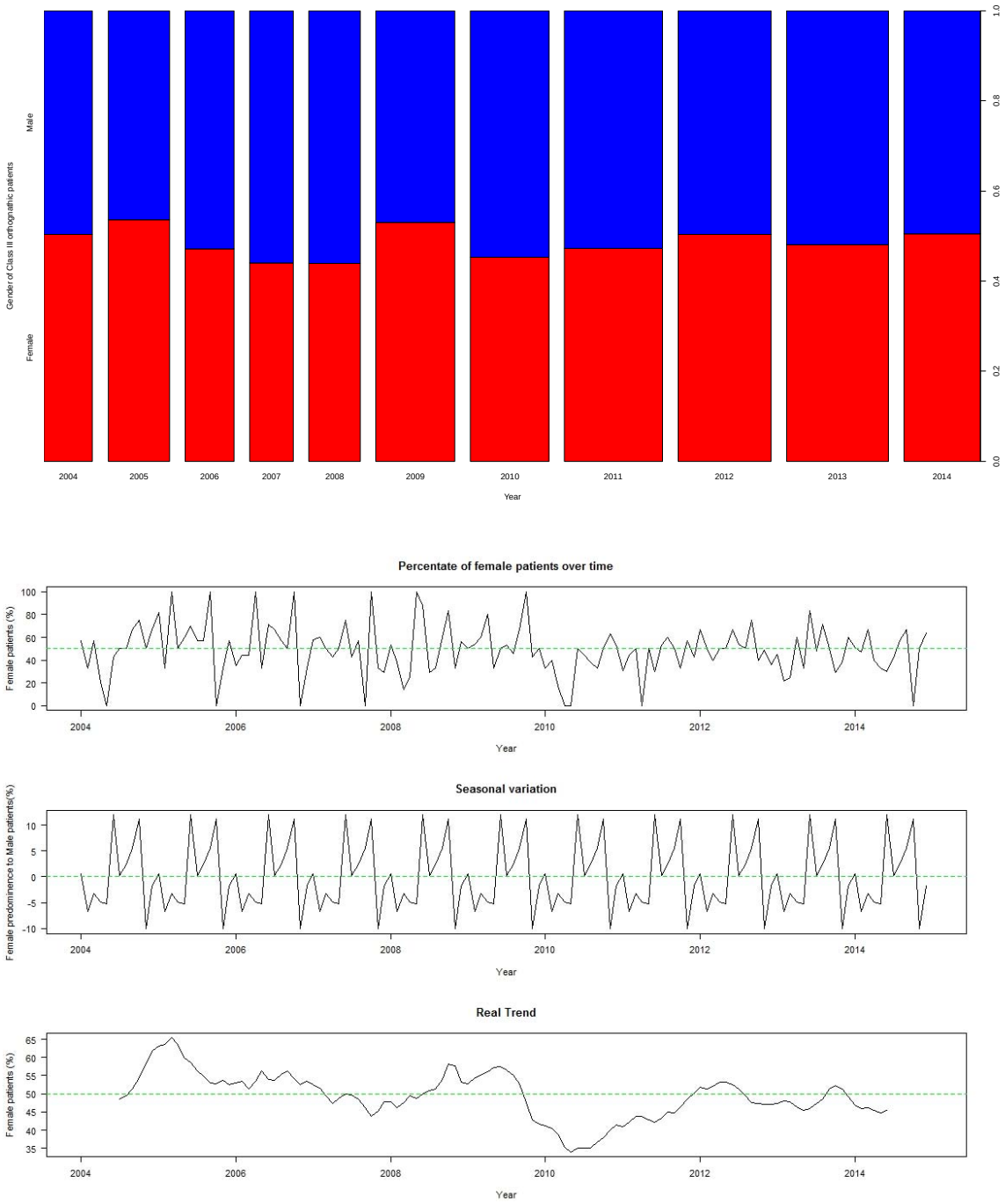

Figure 4. The proportion of female over male patients was approximately 1/2 and has not substantially changed over time.

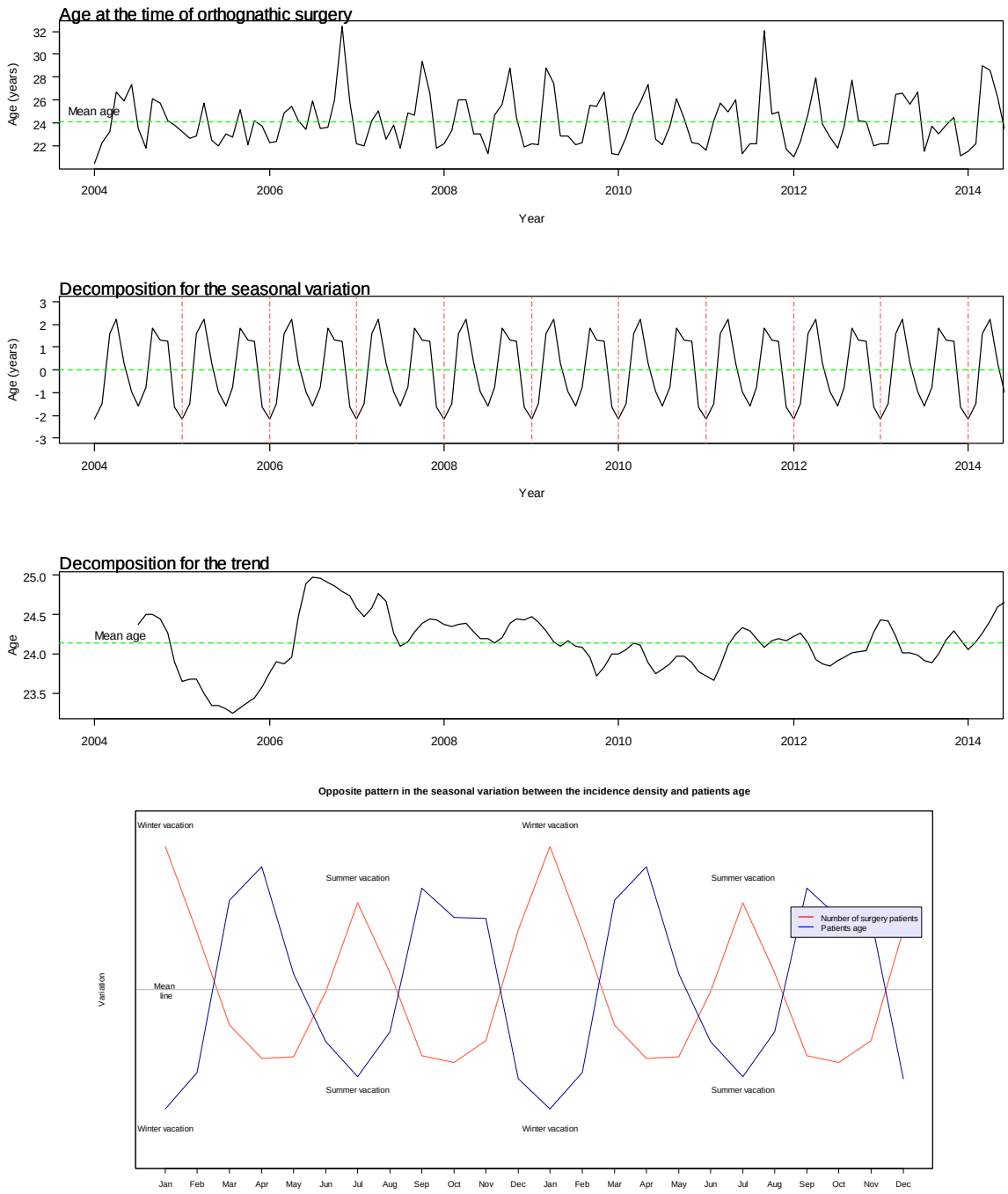

Figure 5. The time series analysis demonstrated a distinct seasonal variation of the age at the time of Class III orthognathic surgery. A large scale view of the seasonal variation (*bottom*) showed an opposite pattern compared to the number of patients. During the vacation seasons, the patients were younger than other times of a year.

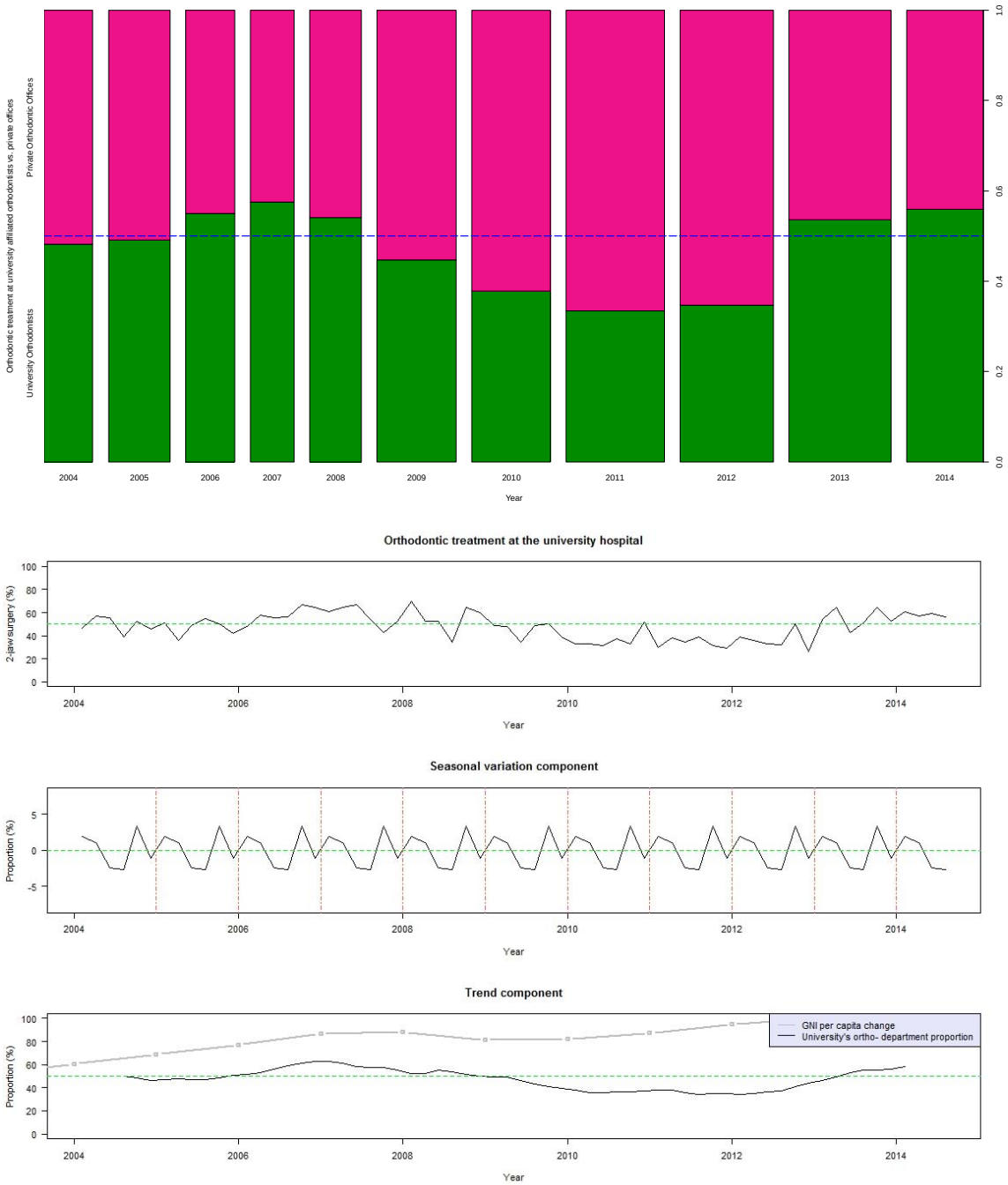

Figure 6. Patients who received orthodontic treatment at private offices were more than 50%, which did not have changed over time.

Figure 7. There was no significant difference in the number of extraction and non-extraction orthodontic treatment performed for the orthognathic surgery patients.

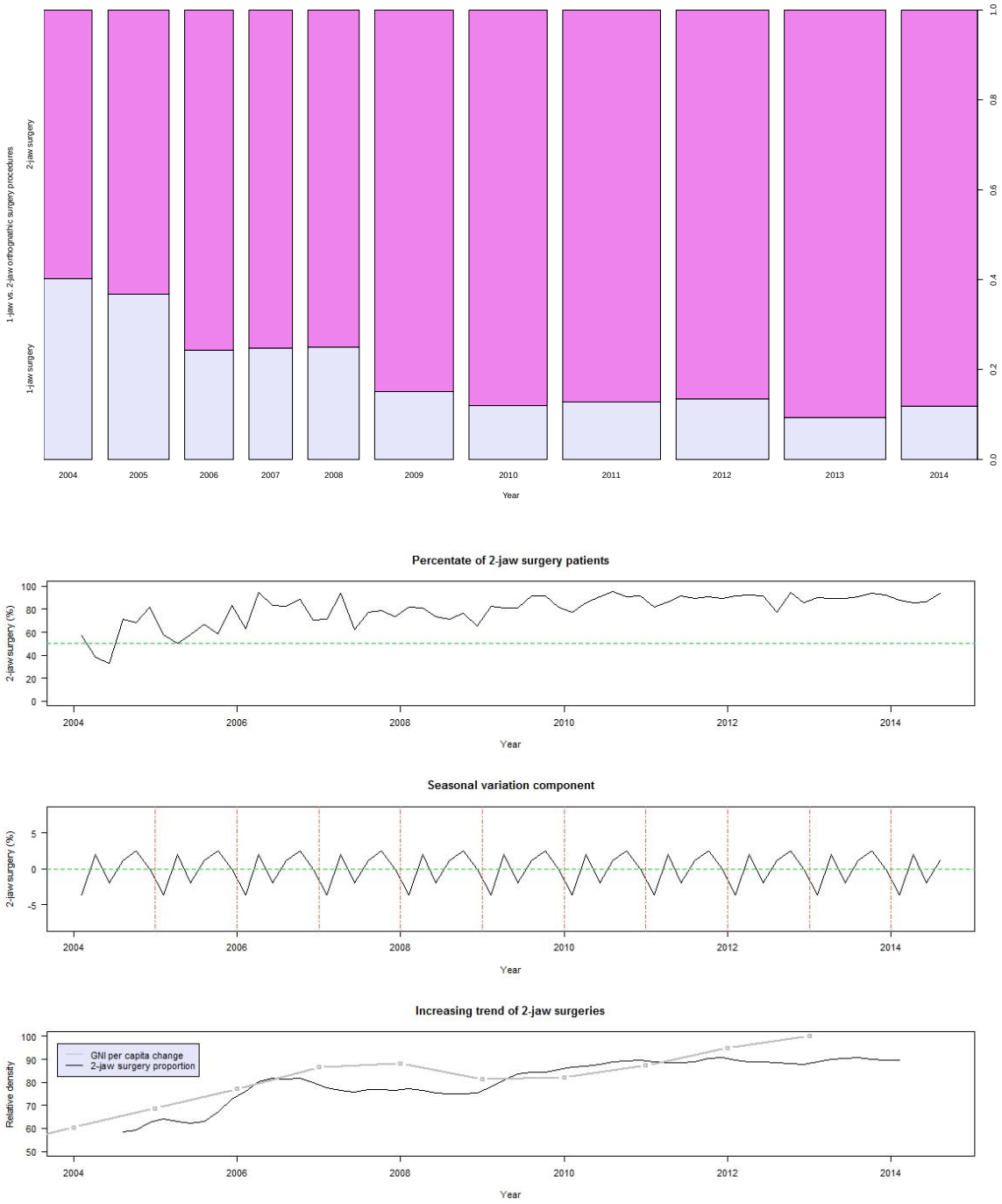

Figure 8. Two-jaw surgeries were performed for 1,831 (82%) patients and by far the most common type of orthognathic surgical procedures. The trend component demonstrated that the spectrum of surgical procedures for Class III patients has changed from 1-jaw to 2-jaw orthognathic surgeries over past decade.

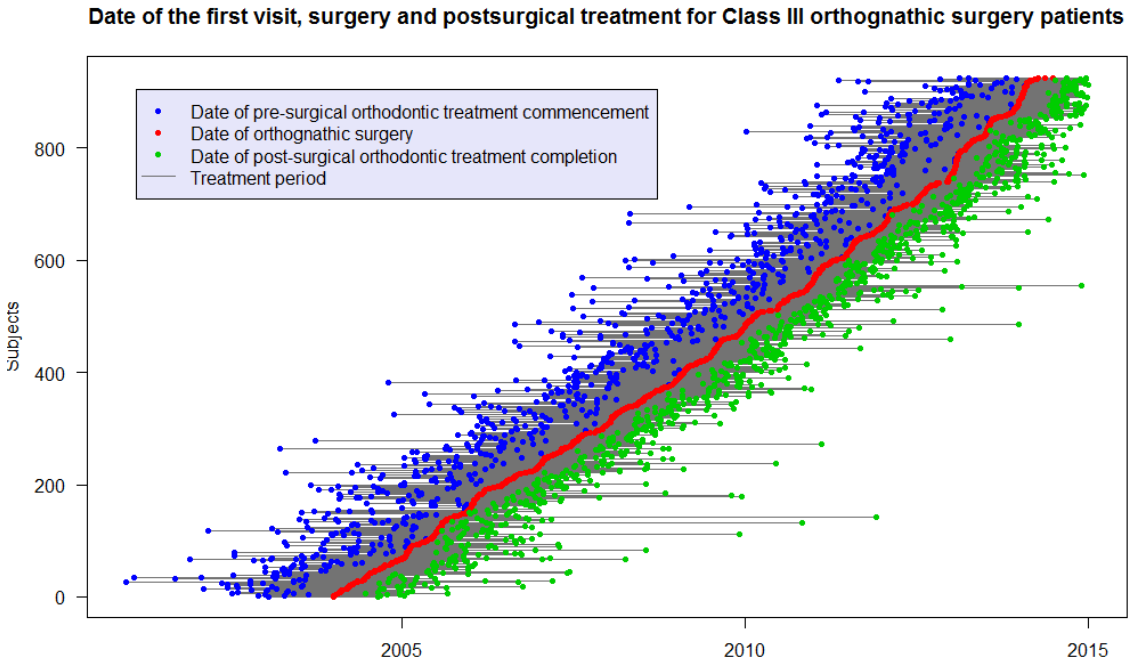

Figure 9. The date of placement of the first active orthodontic component, time of orthognathic surgery, and the date of post-surgical orthodontic treatment completion. Orthodontic treatment time varied significantly for each Class III orthognathic surgery patient.

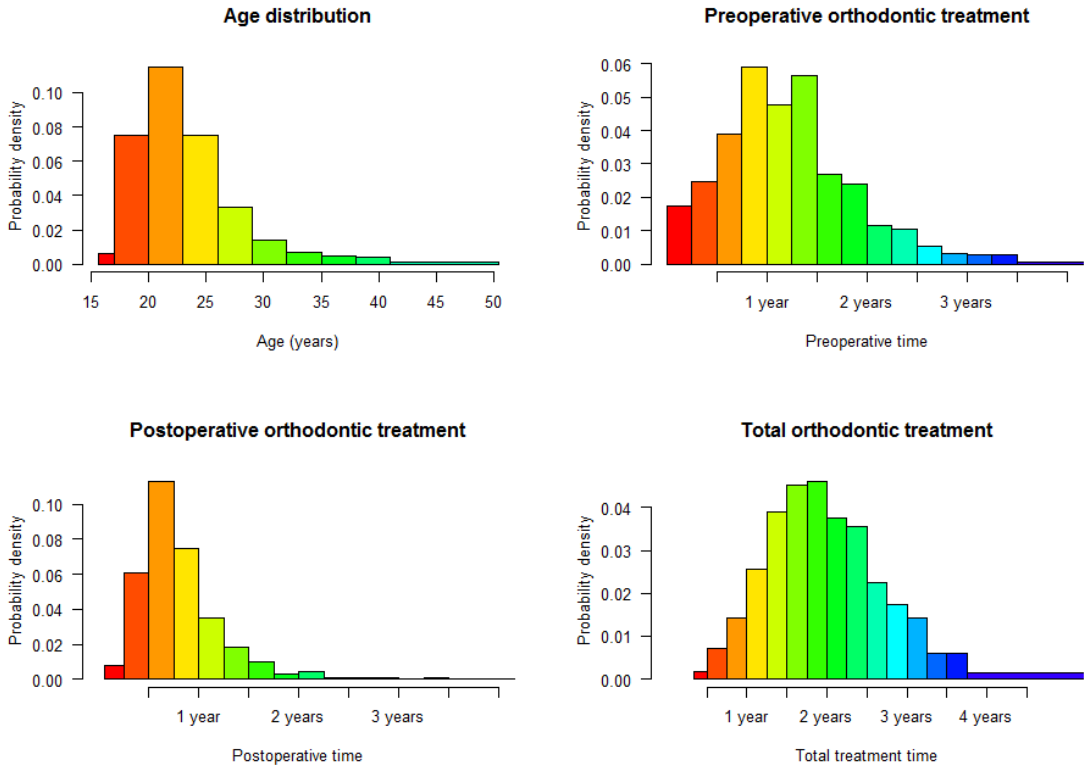

Figure 10. The distribution of all of the time related continuous variables (age at the time of surgery, pre- and post-operative orthodontic treatment time elapsed, and total treatment time) did not show normal Gaussian distribution but demonstrated substantially skewed distribution that could not be normalized via various transformation procedures. The long tails on the right side indicated there existed several patients who were older than others were or received longer treatment than usual.

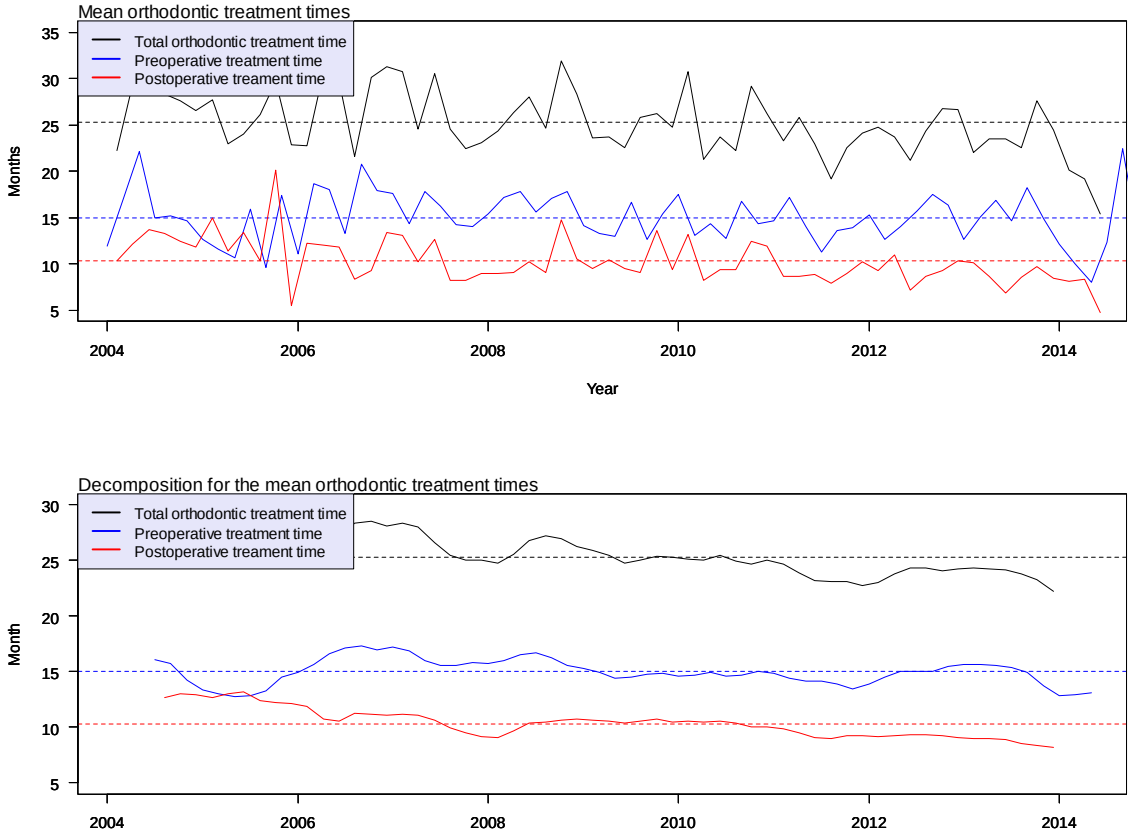

Figure 11. The results of the time series analysis demonstrated that the time durations required for orthodontic treatment before and after Class III orthognathic surgeries have been decreasing over the years.

TABLES

Table 1. All of the orthognathic surgery patients (N = 2,710) from 2004 to 2014

Variables		Frequency		Age		Difference
		n	%	Mean	SD	*P* value
Gender						0.4472
	Female	1,388	51.2	23.7	6.0	
	Male	1,322	48.8	23.5	4.8	
	Total	2,710	100.0	24.8	5.4	
Excluded patients						0.0001
	None	2,610	96.3	23.5	5.2	
	Patients with cleft	61	2.3	23.9	6.8	
	Other anomalies	39	1.4	27.3	13.8	
Patients included (N = 2,610)						
Gender						0.2175
	Female	1,354	51.9	23.6	5.7	
	Male	1,256	48.1	23.4	4.6	
	Total	2,610	100.0			
Classification						<0.0001
	Class I malocclusion	134	5.1	25.6	7.6	
	Class II malocclusion	236	9.0	24.7	6.6	
	Class III malocclusion	2,240	85.8	23.3	4.8	
	Total	2,610	100.0			
Place of orthodontic treatment performed						0.8656
	The same institution	1,256	46.3	23.6	5.1	
	Private practice, transfer	1,454	53.7	23.6	5.7	

SD indicates standard deviation.

Table 2. Class III orthognathic surgery patients (N = 2,240)

Variables		Frequency			Age		*P* value
		n	%		Mean	SD	
Gender							0.2367[a]
	Female	1,092	48.8		23.3	5.3	0.7268[b]
	Male	1,148	51.2		23.2	4.2	
	Total	2,240	100.0		23.3	4.8	
Orthodontic treatment							0.0003[a]
	University orthodontists	1,035	46.2				
	Private practice, transfer	1,205	53.8				
Extraction							0.7998[a]
	Non extraction	1,114	49.7				
	Extraction	1,126	50.3				
Surgery							0.0240[a]
	1-jaw surgery	409	18.3				
	2-jaw surgery	1,831	81.7				
Maxillary surgery							
	None	385	17.2				
	Le Fort 1	1,816	81.1				
	Le Fort 2	26	1.2				
	Le Fort 3	3	0.1				
	Anterior segment osteotomy	10	0.4				
Mandibular surgery							
	None	24	1.1				
	BSSRO	1,904	85.0				
	IVSRO	288	12.9	15%			
	Anterior segment osteotomy	2	0.1				
	Distraction osteotomy	1	0.0				

SD indicates standard deviation; [a] result of the Fisher Exact test to compare the frequency distribution between the two groups. [b] result of *t*-test to compare the mean values between the two groups.

Table 3. Comparisons between the Class III surgery patients who received their orthodontic treatment by university orthodontists at the Department of Orthodontics, Seoul National University Dental Hospital and by private practitioners

Variables		Orthodontic treatment for the Class III surgery patients				*P* value
		University orthodontists		Private practice		
		n	%	n	%	
Gender						0.611[a]
	Female	511	49.4	581	48.2	
	Male	524	50.6	624	51.8	
	Total	1,035	100.0	1,205	100.0	
Extraction						0.471[a]
	Non extraction	506	48.9	608	50.5	
	Extraction	529	51.1	597	49.5	
	Total	1,035	100.0	1,205	100.0	
Surgery						0.476[a]
	1-jaw surgery	182	17.6	227	18.8	
	2-jaw surgery	853	82.4	978	81.2	
	Total	1,035	100.0	1,205	100.0	

[a] result of the Fisher Exact test to compare the frequency distribution between the two groups.

Table 4 Comparison between 1-jaw and 2-jaw orthognathic surgery patients

Variables		Class III orthognathic surgery patients				*P* value
		1-jaw surgery		2-jaw surgery		
		n	%	n	%	
Gender						0.274[a]
	Female	189	46.2	903	49.3	
	Male	220	53.8	928	50.7	
	Total	409	100.0	1831	100.0	
Extraction						0.325[a]
	Non extraction	194	47.4	920	50.2	
	Extraction	215	52.6	911	49.8	
	Total	409	100.0	1831	100.0	
Age		Median	IQR	Median	IQR	0.863[b]
		22.1	(19.9, 24.9)	22.2	(20.0, 25.0)	

[a] result of the Fisher Exact test to compare the frequency distribution between the two groups. [b] result of the two sample Wilcoxon test to compare the median age between the two groups.

Table 5. Types of surgery procedures for the Class III orthognathic surgery patients

Variables		Maxillary surgery					
		None		Advance		Total	
		n	%	n	%	N	%
Mandibular surgery		0.024[a]					
	None		0.0	24	1.1	24	1.1
	Setback	385	17.2	1,831	81.7	2,216	98.9
	Total	385	17.2	1,855	82.8	2,240	100.0
Anterior segmental osteotomy		63	2.8				
	Maxilla	58	2.6				
	Mandible	2	0.1				
	Maxilla + mandible	3	0.1				
Additional surgery							
	Genioplasty	1,091	48.7				
	Paranasal augmentation	78	3.5				
	Zygoma reduction	75	3.3				

[a] result of the Fisher Exact test to compare the frequency distribution between the two groups.

Table 6. Age at the time of surgery and orthodontic treatment time of the Class III surgery patients who received their orthodontic treatment by university orthodontists at the Department of Orthodontics, Seoul National University Dental Hospital

Variables		n	Mean	SD	*P* value†	Median	IQR	*P* value‡
Preoperative orthodontic treatment time (month)								
Pooled data		1,010	14.7	8.2		13.4	(9.3, 18.4)	
Gender	Female	503	14.9	8.2	0.3985	13.9	(9.4, 18.7)	0.3451
	Male	507	14.4	8.1		13.1	(9.0, 18.3)	
Extraction	Non extraction	490	12.0	7.8	<0.0001	10.7	(7.4, 15.2)	<0.0001
	Extraction	520	17.1	7.7		16.6	(12.4, 21.6)	
Surgery	1-jaw surgery	180	15.4	8.1	0.2076	14.1	(10.3, 20.2)	0.1456
	2-jaw surgery	830	14.5	8.2		13.3	(9.0, 18.4)	
Postoperative orthodontic treatment time (month)								
Pooled data		921	10.2	6.6		8.7	(6.5, 11.8)	
Gender	Female	457	9.9	6.4	0.1569	8.3	(6.2, 11.4)	0.0121
	Male	464	10.5	6.8		9.0	(6.8, 12.0)	
Extraction	Non extraction	456	9.6	6.7	0.0046	8.3	(6.1, 10.9)	<0.0001
	Extraction	465	10.8	6.5		9.4	(7.2, 12.4)	
Surgery	1-jaw surgery	173	10.1	8.2	0.9063	8.4	(6.0, 11.4)	0.1139
	2-jaw surgery	748	10.2	6.2		8.8	(6.6, 11.9)	
Total orthodontic treatment time (month)								
Pooled data		921	25.0	10.6		23.4	(17.9, 30.0)	
Gender	Female	457	24.8	10.4	0.5986	23.2	(18.0, 29.0)	0.6075
	Male	464	25.1	10.7		23.5	(17.7, 30.5)	
Extraction	Non extraction	456	21.8	10.3	<0.0001	19.3	(15.3, 25.5)	<0.0001
	Extraction	465	28.0	9.9		26.7	(22.1, 32.4)	
Surgery	1-jaw surgery	173	25.4	11.3	0.6043	22.8	(18.3, 30.5)	0.8476
	2-jaw surgery	748	24.9	10.4		23.5	(17.8, 29.7)	

† result of the Welch two sample *t* test; ‡ result of the two sample Wilcoxon test to compare the treatment time between the two groups.

APPENDIX

```
##############################################################################
###
### Part of the R codings
###    Time series analysis of trends in surgical-orthodontic treatment
###    for Class III patients
###
###    November 1, 2015
###    Composed by Chang-Hoon Lee and Shin-Jae Lee
###    Seoul National University School of Dentistry, Seoul, Korea
###
###    Time Series on monthly basis
###           Example, number of patients from Jan 2004 to Dec 2014
###
##############################################################################


##############################################################################
### Step 1. Dataset preparation
##############################################################################

### According to the format of the original data set,
### it is a possibility to reconstruct the data via 'substring' command,
### such as the followings:

#             head(date.op, 3);str(date.op);class(date.op)
#      op.year       <- substr(date.op, 1,4)
#             head(op.year, 3);    str(op.year); class(op.year)
#      op.month      <- substr(date.op, 6,7)
#             head(op.month, 3); str(op.month); class(op.month)

#      table(op.year);table(op.month)

#      op.year.month <- paste(op.year, op.month, sep=".")

#      (op.year.month <- as.numeric(op.year.month))

#      table(op.year.month)

#      time <-op.year.month
#      time <- unique(time)
```

```
#       time <- time[order(time)];time; length(time)

### For the reader's conveniences, please refer to the following shortcuts.

time <- scan()
  2004.01 2004.02 2004.03 2004.04 2004.05 2004.06 2004.07 2004.08 2004.09
  2004.10 2004.11 2004.12 2005.01 2005.02 2005.03 2005.04 2005.05 2005.06
  2005.07 2005.08 2005.09 2005.10 2005.11 2005.12 2006.01 2006.02 2006.03
  2006.04 2006.05 2006.06 2006.07 2006.08 2006.09 2006.10 2006.11 2006.12
  2007.01 2007.02 2007.03 2007.04 2007.05 2007.06 2007.07 2007.08 2007.09
  2007.10 2007.11 2007.12 2008.01 2008.02 2008.03 2008.04 2008.05 2008.06
  2008.07 2008.08 2008.09 2008.10 2008.11 2008.12 2009.01 2009.02 2009.03
  2009.04 2009.05 2009.06 2009.07 2009.08 2009.09 2009.10 2009.11 2009.12
  2010.01 2010.02 2010.03 2010.04 2010.05 2010.06 2010.07 2010.08 2010.09
  2010.10 2010.11 2010.12 2011.01 2011.02 2011.03 2011.04 2011.05 2011.06
  2011.07 2011.08 2011.09 2011.10 2011.11 2011.12 2012.01 2012.02 2012.03
  2012.04 2012.05 2012.06 2012.07 2012.08 2012.09 2012.10 2012.11 2012.12
  2013.01 2013.02 2013.03 2013.04 2013.05 2013.06 2013.07 2013.08 2013.09
  2013.10 2013.11 2013.12 2014.01 2014.02 2014.03 2014.04 2014.05 2014.06
  2014.07 2014.08 2014.09 2014.10 2014.11 2014.12


#Surgery$Freq <- rep(1, nrow(Surgery))     #Surgery, name of the data set
#       (tapply(Freq, op.year.month, sum) -> table.freq)
#       as.matrix(table.freq)-> mat.freq
#       (Freq <- mat.freq[ ,1]) ; length(Freq)

### In case the data file is absent, please scan the followings.

Freq <- scan()
  15 13 11 10  7 11 19 12 11  8  8 14 19 26  7  7 12 19 24 27  9  3  8 16
  34 20 16  3  5 13 11 12  4  5  5 12 15 13  9  8  8 13 12 14  7  7  6 13
  22 11 12  9  5 14 20 18  9  8  6 14 26 25 13  8  8 18 35 27  7  5 20 34
  24 34 16  5 10 22 29 16  9 12 15 33 50 33 19 10 11 24 42 22 13  9 15 33
  51 31 15 10  9 15 48 30  9  9  6 36 62 29 14 14 10 18 46 17  7 10 16 47
  61 28  6  8  6 16 34 12  5  4  9 31
```

```
##############################################################################
### Step 2. Time series graphics
##############################################################################

ts.Freq <-ts(Freq, start=c(2004,1), end=c(2014,12), frequency=12)
print(ts.Freq)

### Decomposition for seasonal variation and real trend
       decomp.Freq   <- decompose(ts.Freq)
       round(decomp.Freq$season[1:132],1);
       round(decomp.Freq$trend[1:132],1)

### Multi-frame graphics
par(mfrow=c(4,1))


### 1) Number of Class III surgery patients over the years
plot.ts(ts.Freq,
              las=1, adj=0,
              main="Number of Class III surgery patients over the years",
              xlim=c(2004, 2014), xlab="Year", adj=0.5,
              ylab="Frequency")
       abline(h=mean(Freq), col="green", lty=2)
       text(2004, mean(Freq)+10, "Mean incidence \n per month", adj=0)
       mtext("Number of Class III surgery patients over the years", adj=0)


### 2) Seasonal variation
plot(decomp.Freq$seasonal,
              main="Seasonal variation for the number of Class III surgery
patients",
              las=1,
              xlim=c(2004, 2014), xlab="Year",
              ylab="Relative incidence",
              ylim=c(-22,22) )
       abline(h=0, col="green", lty=2)
       abline(v=seq(from =2005, to = 2014, by=1), col='tomato', lty=4)
       mtext("Decomposition for the seasonal variation", adj=0)
```

```
### 3) Seasonal variation, magnification
plot(1:24, decomp.Freq$seasonal[1:24],
              main="Seasonal variation - magnified view",
              las=1, type="l",
              xlim=c(1, 24),
              xlab="",
              ylab="Relative incidence",
              xaxt="n",
              ylim=c(-22,22) )
       abline(h=0, col="green", lty=2)
       axis(side = 1,
       at = 1:24,
       labels=c( 'Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun',
                     'Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec',
                     'Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun',
                     'Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec'   ))
       text(c(1.2, 13),rep(22, 2), "Winter vacation")
       text(c(7, 19),rep(15, 2), "Summer vacation")
       mtext("Seasonal variation", adj=0)


### 4) Trend component after the time series analysis
plot(decomp.Freq$trend,
              main="Trend component after the time series analysis \n
                     (increasing number of Class III surgery patients)",

              las=1,
              xlim=c(2004, 2014), xlab="Year",
              ylab="Frequency")
       abline(h=mean(Freq), col="green", lty=2)
       text(2004, mean(Freq)+3, "Mean incidence \n per month", adj=0)
       mtext("Decomposition for the trend", adj=0)


##############################################################################
### More detailed/entire codings are available upon request to the author.
### Thank you very much.
##############################################################################
```