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Research article

# Examination of coronoid foramen and coronoid canal with CBCT

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A R T I C L E I N F O

*Keywords:*
Anatomical variation
Coronoid process
Coronoid canal
Coronoid foramen
Mandible

A B S T R A C T

*Objective:* This study aimed to examine the coronoid foramen using CBCT not only according to its localization, distribution to gender and age but also to determine whether there are canals associated with the coronoid foramen and to identify them and their clinical significance.
*Methods:* 488 images obtained between 2022 and 2023 were retrospectively evaluated in sagittal, horizontal, and coronal sections. During the evaluation of the images, the number and localization of the coronoid foramen and the coronoid canals originating from this foramen were recorded and examined. In addition, the patient images were divided into different age groups and the presence of coronoid foramen was analyzed.
*Results:* Coronoid foramen was detected in 5.1 % and coronoid canal in 1.6 % of the images. Unilateral coronoid foramen was found in 1.4 % and bilateral coronoid foramen was found in 3.7 % of the patients. Unilateral coronoid canal was found in 1.0 % and bilateral coronoid canal in 0.6 % of the patients. When the presence of coronoid foramen was analyzed according to age groups, no significant difference was found between age groups.
*Conclusion:* Recognition of the coronoid foramen and coronoid canal will not only reduce the likelihood of complications in surgical procedures but also influence the treatment plan. Further research is needed to recognize the content of this variations.

## 1. Introduction

Anatomical variations are defined as deviations from the expected arrangement of an anatomical structure, without causing any impairment in its function [1]. Many anatomical variations have been described in the science of anatomy [2]. Some anatomical variations may cause complications in clinical practice and lead to problems in diagnosis [1]. Anatomical variations are also observed in the mandible, which is the largest and most durable bone among the facial bones [3,4]. Surgical interventions for the mandible may cause complications such as bleeding and sensory disturbances due to artery, vein, and nerve damage through abnormal structures in the mandible [5,6]. In the past, anatomical variations were reported by surgical procedures using cadavers, but nowadays medical imaging systems are also used [7]. Cone beam computed tomography (CBCT) scans obtained with a larger Field of View (FOV) are important to prevent possible complications because they allow us to see various incidental findings, anatomical variations and pathologies [8]. The American Academy of Oral and Maxillofacial Radiology (AAOMR) and the European Academy of Dentomaxillofacial Radiology (EADMFR) have described that all CBCT images within the FOV should be analyzed attentively [9,10]. CBCT has made it possible to obtain clearer images by allowing the target structure to be examined in all directions of space by taking different cross-sectional images to reveal anatomical variations, high resolution, detail reflection capacity, clarity in hard tissue imaging, low

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metal artifact, ease of use and relatively low radiation dose [11–13].

The quadrangular section on the posterior side of the mandible is called the ramus. It contains the coronoid process and condylar process on the ramus. The coronoid process is the triangular structure on the upper anterior side of the ramus [14].

For the first time in 2018, Firdoose described accessory foramina associated with bilateral coronoid foramina as an anatomical variation in the coronoid process. Before that, there was no information in the literature about coronoid foramina in the human mandible [3]. The aim of this study was not only to examine the coronoid foramina according to their localization, distribution according to gender and age groups using CBCT but also to understand whether there are canals associated with the coronoid foramen and to identify them and to indicate their importance in the clinic. In addition, it eliminates the lack of evaluation of the coronoid foramen and coronoid canal frequency in the literature.

### 1.1. Material and method

Ethics committee approval for this study was obtained from the Harran University Clinical Research Ethics Committee with decision number 23.21.03. Before the images were obtained, an informed consent form was provided from the patients for the use of the images in scientific studies. Estimation of the sample size of the research was made using the G*Power 3.1.9.7 program. Considering the $\alpha = 0.05$, $1\text{-}\beta = 0.90$ effect size as medium, the sample size for the chi-square test was found to be 183. 726 CBCT images obtained between 2022 and 2023 from patients admitted to the Harran University Faculty of Dentistry for various reasons were analyzed. The age, gender, and medical history of all patients were obtained from hospital records. Images where the ramus and coronoid region enter the imaging area, CBCT images that do not contain artifacts, have not had coronoid surgery, do not contain coronoid fractures, do not contain large tumors and cysts extending to the coronoid and ramus and whose tomographic image is optimal for examination are included. Among these images, 238 images were excluded due to insufficient imaging area, artifacts in the image, images taken for follow-up purposes, incompatibility with general imaging parameters, poor image quality, systemic diseases in the jaw bones, cysts, tumors, and fractures in the examined area.

A Castellini X-Radius Trio Plus dental tomography (Imola, ITALY) with 90 kVp and 16 mAs irradiation parameters was used to obtain the images. The FOV of the images was 13 × 10 and 13 × 16 cm with a voxel size of 0.3 mm and a slice thickness of 1 mm. All images were retrospectively evaluated in sagittal, horizontal, and coronal sections by a single dental maxillofacial radiologist using the IRYS viewer 15.1 software program. In doubtful cases, a dental maxillofacial radiologist (M.E.D) with 5 years of experience was consulted. 20 % of all images were re-examined to assess intra-observer reliability. During the evaluation of the images, the number and localization of the coronoid foramen and the coronoid canals originating from these foramen were recorded (Figs. 1–2). Patient images were divided into 7 age groups 0–10, 11–20, 21–30, 31–40, 41–50, 51–60 and 60 years older, the presence of coronoid foramen was analyzed. A full HD screen with a screen size of 15.6 inches and a maximum screen resolution of 1920 × 1080 was used to examine all images.

### 1.2. Statistical analysis

Data were analyzed using the IBM SPSS Statistics Version 25 package program (Armonk, New York, USA). Descriptive statistics were used to calculate number (N), percentage, mean, standard deviation, minimum and maximum values. Kolmogorov Smirnov test was performed to examine the normal distribution of the data. Pearson chi-square test was applied to examine the relationship between categorical variables. Intraobserver agreement was evaluated by kappa statistical analysis. $P < 0.05$ was accepted as a significance level.

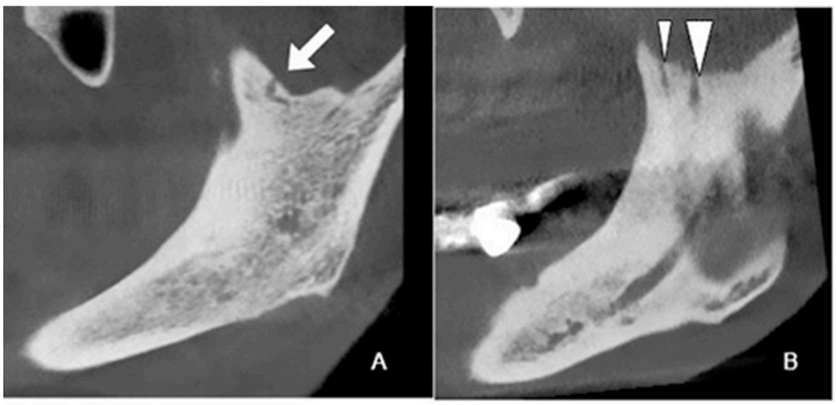


**Fig. 1.** CBCT sagittal section image of coronoid foramen in A, CBCT sagittal section image of coronoid canal in B.

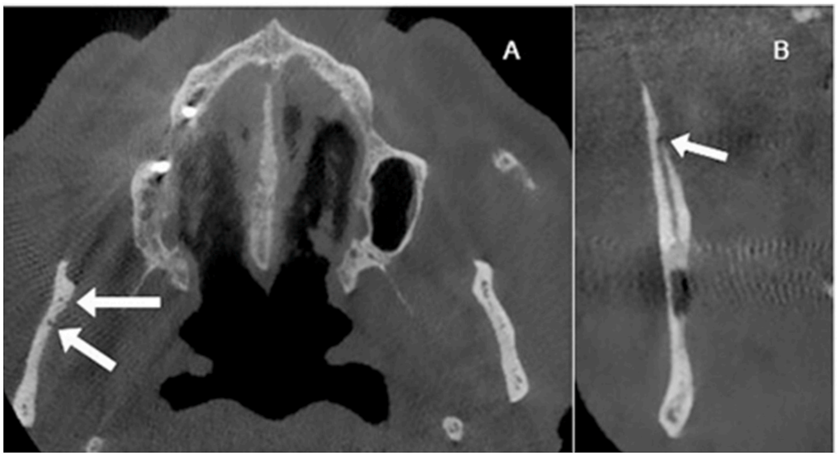


**Fig. 2.** CBCT axial image arrowheads point to the coronoid canal in A, CBCT coronal section image arrowheads point to the coronoid canal in B.

## 2. Results

Intraobserver reliability was found to be good (0.88). Among the 488 participants with a mean age of 34.99 years and an age range of 6–81 years, 251 (51.4 %) were female and 237 (48.6 %) were male. Coronoid foramen was detected in 5.1 % and coronoid canal in 1.6 % of the images. Unilateral coronoid foramen was found in 1.4 % and bilateral coronoid foramen was found in 3.7 % of the patients. Unilateral coronoid canal was found in 1 % and bilateral coronoid canal in 0.6 % of the patients. The distribution of the right and left coronoid foramen is shown in Table 1. The rate of right coronoid foramen was 4.3 % while the rate of left coronoid foramen was 4.6 %. The absence of right and left coronoid foramen together was statistically more common and significant than the presence of right and left coronoid foramen together ($p < 0.001$). The rate of right coronoid canal was 1.6 %, while the rate of left coronoid canal was 0.6 %. The absence of the right and left coronoid canal together was statistically more common and significant than the presence of the right and left coronoid canal together ($p < 0.05$). The distribution of the coronoid foramen according to gender is shown in Table 2. When the presence of coronoid foramen was evaluated according to gender, no statistically significant difference was found ($p > 0.05$). The analysis of the coronoid foramen according to age groups is shown in Table 3. When the presence of coronoid foramen was analyzed according to age groups, no significant difference was found between age groups ($p > 0.05$). The rate of coronoid foramen was 5.5 % in female and 4.8 % in male. Right coronoid foramen was seen in 2 % of female and 2.3 % of male. The rate of left coronoid foramen was 2.3 % in both male and female. There was no statistically significant difference in the distribution of right and left coronoid foramen between genders ($p > 0.05$). The right coronoid canal was observed in 0.8 % of both male and female. The left coronoid duct was 0.4 % in female and 0.2 % in male. There was no statistically significant difference in the distribution of the right and left coronoid canals between genders ($p > 0.05$). The right coronoid canal originating from the right coronoid foramen was observed in 1.6 % of the patients, while the left coronoid canal associated with the left coronoid foramen was observed in 0.6 % of the patients.

## 3. Discussion

Anatomical variations can appear in different parts of the body. Many studies have been conducted on these variations. Despite the variations described in detail in the literature, many variations are still being reported [1,15]. The coronoid foramen and coronoid canal, which are among these variations, were examined in this study. While the presence of a coronoid foramen was also detected in cases with a coronoid canal, the coronoid canal was not observed in some cases with a coronoid foramen. Presence of coronoid canal and coronoid foramen did not show any gender and age groups tendency.

When the literature was reviewed, six studies examining the coronoid foramen in humans were found, however, there is no study examining the frequency of the coronoid canal in humans [3,13,16–19]. Four of these six studies are case report studies. In 2018, Firdoose drew attention to the phylogenetic hypothesis while describing the coronoid foramen, which had previously been described

**Table 1**
The distribution of the right and left coronoid foramen.

| | | Left coronoid foramen | | Total | P |
|---|---|---|---|---|---|
| | | Presence | Absence | | |
| Right coronoid foramen | Presence | 18 (3.7) | 3 (0.6) | 21 (4.3) | <0.001 |
| | Absence | 4 (0.8) | 463 (94.9) | 467 (95.7) | |
| Total | | 22 (4.5) | 466 (95.5) | 488 (100.0) | |

Data are presented as n (%).

**Table 2**
Dispersion of the coronoid foramen according to gender.

| | | Gender | | Total | P |
|---|---|---|---|---|---|
| | | Female | Male | | |
| Right coronoid foramen | Presence | 10 (2.0) | 11 (2.3) | 21 (4.3) | 0.890 |
| | Absence | 241 (49.4) | 226 (46.3) | 467 (95.7) | |
| Left coronoid foramen | Presence | 11 (2.3) | 11 (2.3) | 22 (4.6) | 0.721 |
| | Absence | 240 (49.1) | 226 (46.3) | 466 (95.4) | |

Data are presented as n (%).

**Table 3**
Distribution of coronoid foramen according to age.

| Age groups (in years) | 0–10 | 11–20 | 21–30 | 31–40 | 41–50 | 51–60 | >60 | Total | P |
|---|---|---|---|---|---|---|---|---|---|
| Absence of coronoid foramen | 23(4.7) | 98(20.1) | 108(22.2) | 60(12.3) | 71(14.5) | 58(11.9) | 45(9.2) | 463(94.9) | 0.462 |
| Presence of coronoid foramen | 1 (0.2) | 2(0.4) | 5(1.0) | 3(0.6) | 4(0.9) | 5(1.0) | 5(1.0) | 25(5.1) | |
| Total | 24(4.9) | 100(20.5) | 113(23.2) | 63(12.9) | 75(15.4) | 63(12.9) | 50(10.2) | 488(100.0) | |

Data are presented as n (%).

in the proboscis, for the first time in humans [3,20]. In his case report on bilateral coronoid foramen, Firdoose emphasized the possibility of a neurovascular bundle passing through this foramen with an advanced magnetic resonance imaging system [3]. Unfortunately, the content of the coronoid canal or coronoid foramen could not be determined by magnetic resonance imaging since this study was a retrospective study based on hospital records. In another case report published in 2019, the coronoid foramen seen with the trifid mandibular canal was discussed and the importance of recognizing variations to prevent possible damage in surgical procedures involving the coronoid process was emphasized in this case report [16]. In 2021, the bilateral coronoid foramen, left accessory coronoid foramen and left coronoid canal observed in a Saudi woman was mentioned in a case report on the subject, and attention was drawn to the phylogenetic hypothesis related to the coronoid canal. In this case report, accessory coronoid foramen and coronoid canal were mentioned for the first time [17]. In 2023, Ghousia and Firdoose presented a case report in which bilateral coronoid foramen with the coronoid canal on the right side was examined in a pediatric patient. In Ghousia and Firdoose's studies, coronoid foramen and coronoid canal were mentioned for the first time in a pediatric patient [18].

The clinical importance of this study is to emphasize that the neurovascular structures inside the coronoid foramen and coronoid canal may be damaged in interventional procedures such as coronoid hyperplasia, coronoid fractures and coronoid graft harvesting [21–23]. As a result of this study, in parallel with the results of previous studies, it was thought that knowing the presence of the coronoid canal and coronoid foramen would prevent complications that may occur in surgical procedures to be performed [16–18]. In addition to the occurrence of conditions such as paresthesia, excessive bleeding, and traumatic neuroma as a result of a violation of the structural integrity of these anatomical variations in surgical procedures due to anatomical variations in the body, it has been reported that some anatomical variations may play a role in the spread of tumor cells following radiotherapy [24,25]. In this study, the idea that it would be easy for tumor cells to spread through neurovascular bundles in the coronoid foramen, accessory, and coronoid canal was adopted. Gündüz et al. and Firdoose et al. examined the frequency of coronoid foramen according to age and gender [13,19]. It was supposed that the reason for the difference in the total rate of the coronoid foramen, bilateral and unilateral rates between the study conducted by Gündüz et al. and this study was the difference in sample size and geographical differences. In addition, immigration movement in the region where the study was conducted may have a role in this difference by affecting the ethnic distribution. The fact that the total rate of coronoid foramen, bilateral and unilateral presence of coronoid foramen in the study by Firdoose et al. and the total rate of coronoid foramen, bilateral and unilateral presence of coronoid foramen in this study are relatively close to each other strengthens this assumption [19]. In the studies conducted by Firdoose et al. and Gündüz et al. there was no significant difference between the rates when the total rate of coronoid foramen, bilateral or unilateral presence, or localization of coronoid foramen were evaluated by gender [13,19]. In this study, there was no significant correlation between coronoid foramen frequency and age groups in parallel with the study of Gündüz et al. [13]. However, some variant types were found to be significant in some age groups in the study by Firdoose et al. [19] In this study, only the presence and absence of coronoid foramen were evaluated between age groups due to the difference in sample size and there was no statistically significant difference. Various foramina and canals are expected to close with obliteration in the first year of life, but if this does not appear, they can be observed as anatomical variations in adults [19]. In this case, it was thought that the distribution of these variations according to various age groups after the completion of development would be coincidental.

Information about the anatomical variations in the coronoid process will affect surgical planning by enabling surgical interventions such as grafting in this part of the mandible to be performed more cautiously [26]. In addition, it was observed that the location of the coronoid canal was likely to be confused with the fracture line due to its structure and it was thought that knowing this structure would prevent misdiagnosis.

### 3.1. Limitations

Some parameters could not be discussed due to lack of information about the coronoid canal in the literature. The contents and histological structures of the coronoid canal and coronoid foramen could not be examined. The possible obliteration process of the coronoid canal and coronoid foramen could not be followed. Current clinical conditions could not be accessed because all information was obtained retrospectively from hospital records.

Although this study has external validity, it is recommended to apply it in communities where different races live together to increase external validity due to racial differences.

## 4. Conclusion

Diagnosis of the coronoid foramen and coronoid canal will prevent complications in coronoid surgical procedures, allow differentiation of pathologic conditions with these anatomic variations, and affect the treatment plan. The presence of coronoid foramen and coronoid canal did not show any significant difference according to age groups and gender. The presence of a coronoid canal requires the presence of a coronoid foramen. However, the presence of the coronoid foramen does not always mean that there will be a coronoid canal. Magnetic resonance imaging systems and histologic studies in dissected mandibles are recommended to understand the content of the coronoid foramen and coronoid canal. This variation should be investigated in children and the obliteration process of the variation should be evaluated in young age groups. This variation should be investigated with more numbers and in different regions.

## Data availability statement

Raw data for datasets are not publicly available to preserve individuals' privacy under the European General Data Protection Regulation but are available from the corresponding author upon reasonable request.

## Ethics approval

This study was reviewed and approved by Harran University Clinical Research Ethics Committee with the approval number: [23.21.03], dated [November 13, 2023].

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## CRediT authorship contribution statement

**Mehmet Emin Dogan:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Menduh Sercan Kaya:** Writing – original draft, Methodology, Investigation, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## References

[1] A. Saniotis, M. Henneberg, Anatomical variations and evolution: re-evaluating their importance for surgeons, ANZ J. Surg. 91 (5) (2021) 837–840.
[2] J. Sañudo, R. Vázquez, J. Puerta, Meaning and clinical interest of the anatomical variations in the 21st century, Eur. J. Anat. 7 (2003) 1–4.
[3] N.F. Chintamani Subhan, Bilateral 'coronoid foramina'with accessory foramina on the 'lateral aspect of ramus' of mandible: an unseen variance discovery in humans, Surg. Radiol. Anat. 40 (6) (2018) 641–646.
[4] J. Valenzuela-Fuenzalida, C. Cariseo, M. Gold, D. Díaz, M. Orellana, J. Iwanaga, Anatomical variations of the mandibular canal and their clinical implications in dental practice: a literature review, Surg. Radiol. Anat. 43 (2021) 1259–1272.
[5] P.N. Mistry, J. Rajguru, M.R. Dave, Study of the accessory mandibular foramina in dry adult human mandibles and their clinical and surgical implications, Int. J. Anat. Radiol. Surg. 10 (2021) 16–19.
[6] T. Kawai, R. Asaumi, Y. Kumazawa, I. Sato, T. Yosue, Observation of the temporal crest canal in the mandibular ramus by cone beam computed tomography and macroscopic study, I Int. J. Comput. Assist. Radiol. Surg. 9 (2014) 295–299.
[7] J.C. McLachlan, D. Patten, Anatomy teaching: ghosts of the past, present and future, Medical education 40 (3) (2006) 243–253.
[8] J.B. Price, K.L. Thaw, D.A. Tyndall, J.B. Ludlow, R.J. Padilla, Incidental findings from cone beam computed tomography of the maxillofacial region: a descriptive retrospective study, Clin. Oral Implants Res. 23 (2012) 1261–1268.

[9] L. Carter, A. Farman, J. Geist, et al., American academy of oral and maxillofacial radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography, Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 106 (2008) 561–562.
[10] K. Horner, M. Islam, L. Flygare, K. Tsiklakis, E. Whaites, Basic principles for use of dental core beam computed tomography; consensus guidelines of the European Academy of Dental and Maxillofacial Radiology, Dentomaxillofac. Radiol. 38 (2009) 187–195.
[11] S.C. White, M.J. Pharoah, Oral Radiology-E-Book: Principles and Interpretation, Elsevier Health Sciences, 2014.
[12] M. Naitoh, K. Nakahara, Y. Suenaga, K. Gotoh, S. Kondo, E. Ariji, Variations of the bony canal in the mandibular ramus using cone-beam computed tomography, Oral Radiol. 26 (2010) 36–40.
[13] K. Gunduz, G. Serindere, H. Avsever, K. Orhan, A detailed CBCT study of 'coronoid foramina'and accessory foramina of the mandible: a unique anatomic variation, Acta Clin. Croat. 58 (4) (2019) 1–8.
[14] S. Standring, Gray's Anatomy E-Book: the Anatomical Basis of Clinical Practice, Elsevier Health Sciences, 2021.
[15] G. Georgiev, Significance of anatomical variations for clinical practice, Int. J. Anat. Var. 10 (3) (2017) 43–44.
[16] N. Firdoose, Concurrent 'coronoid foramen'with trifid mandibular canal in a live human: CBCT exploration of a unilateral variant, Eur. J. Anat. 24 (3) (2020) 229–234.
[17] N. Firdoose, Accessory coronoid foramen" synchronous with" bilateral coronoid foramina" and double mandibular canal–distinctive triad of mandibular anatomic variants in a live human, CBCT exploration. Stomatologija 23 (1) (2021) 16–21.
[18] S. Ghousia, C.N. Firdoose, Coronoid foramina in a pediatric mandible: an incidental finding of a morphologic and developmental anatomic variant as a distinctive documented feature, Natl. J. Clin. Anat. 10 (1) (2021) 51–54.
[19] N.F. Chintamani Subhan, M.M. Awadalla AlSaleh, G. Begum Syed, S.U. Khair, Clinical anatomy of coronoid foramina of mandible and review of its implications in maxillofacial surgery, Surg. Radiol. Anat. 45 (4) (2023) 445–452.
[20] M.P. Ferretti, R. Debruyne, Anatomy and phylogenetic value of the mandibular and coronoid canals and their associated foramina in proboscideans (Mammalia), Zool. J. Linn. Soc. 161 (2) (2011) 391–413.
[21] S. Amrani, G.E. Anastassov, A.H. Montazem, Mandibular ramus/coronoid process grafts in maxillofacial reconstructive surgery, J. Oral Maxillofac. Surg. 68 (3) (2010) 641–646.
[22] R. Pathak, T.P. Kale, S.M. Kotrashetti, H. Patel, Interventions for the management of mandibular coronoid process fractures: a systematic review, J. Maxillofac. Oral Surg. 22 (2) (2023) 433–441.
[23] S. Yura, N. Ohga, K. Ooi, Y. Izumiyama, Mandibular coronoid hyperplasia: a case report, Cranio 27 (4) (2009) 275–279.
[24] Y.Y. Choi, S.S. Han, Double mandibular foramen leading to the accessory canal on the mandibular ramus, Surg. Radiol. Anat. 36 (2014) 851–855.
[25] S.S. Han, J. Hwang, C. Park, The anomalous canal between two accessory foramina on the mandibular ramus: the temporal crest canal, Dentomaxillofac. Radiol. 43 (7) (2014) 20140115.
[26] S. Sabhlok, P.P. Waknis, K.S. Gadre, Applications of coronoid process as a bone graft in maxillofacial surgery, J. Craniofac. Surg. 25 (2) (2014) 577–580.