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ORIGINAL ARTICLE

Morphological evaluation of the coccyx with multidetector computed tomography

Azad Hekimoglu[1] · **Onur Ergun**[1]

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Abstract

Purpose This study aims to evaluate the morphology of the coccyx in adults with multidetector computed tomography and to contribute to the classification of the coccyx using intercoccygeal and sacrococcygeal angle measurements.

Methods The pelvic computed tomography images of 224 patients were retrospectively evaluated. The multiplanar reconstruction and 3D volume rendering images of the coccyx were obtained from all patients at sagittal and coronal planes. The morphology of the coccyx, number of bone segments, the presence of scoliosis, and presence of sacrococcygeal and intercoccygeal fusion were evaluated. After the measurement of coccygeal length, width, and thickness, intercoccygeal and sacrococcygeal angles were also calculated in all patients.

Results The morphological classification showed that 136 patients (60.7%) had type 1, 65 patients (29%) had type 2, and 17 patients (7.6%) had type 3 coccyx. The intercoccygeal angle was zero degree in five patients (type 0) and one patient had retroverted coccyx (type 5). The coccyx had four segments in 155 patients (69.2%), three segments in 52 patients (23.2%), five segments in 15 patients (6.7%), two segments in one patient (0.4%), and one segment in one patient (0.4%).

Conclusion We determined patients with an intercoccygeal angle of zero degree, which is not mentioned in the literature before, and we propose to use the term "type 0" for these patients in the classification of coccyx. The coccygeal measurements and classification will be instructive for the radiologists and have a guiding role for the future studies.

Keywords Anatomic variation · Coccyx · Morphological findings · Multidetector computed tomography

Introduction

Although the structures constituting the skeletal system have a similar appearance, some structures like the xyphoid bone [2] show individual deviations. Another example is the coccyx, the last rung of the vertebral column. Although all segmental structures of the vertebral column are similar in all people regarding the number and structure, coccyx may show an interindividual deviation in number and structure. The number of vertebrae may change between three and five, although the usual number of coccygeal vertebrae is four [12]. According to some studies, coccyx might also have more segments [8]. The first coccygeal segment, which forms the joint between coccyx and sacrum, is the widest one and the following segments become narrower [9]. The caudal part stands free and supports the pelvic floor together with the levator ani and iliococcygeus muscles and various ligaments. The length of coccyx varies between individuals and only 10% is related with the length [8]. The coccygeal morphology may show not only individual but also ethnic variations [1, 7].

The classification of the coccygeal morphology was first described by Postacchini et al. and four types were defined [9]. Later, a fifth type was described in two separate studies with different namings [4, 14].

The objective of this study was to investigate the size, form, and the number of segments of the coccyx in adults with the help of multidetector computed tomography (CT) and to evaluate the presence of sacrococcygeal and intercoccygeal fusion and to establish coccygeal classification using sacrococcygeal and intercoccygeal angle measurements.

✉ Azad Hekimoglu
azadhekimoglu@gmail.com

Onur Ergun
onurergun@yahoo.com

[1] Department of Radiology, Diskapi Yildirim Beyazit Training and Research Hospital, 06110 Diskapi/Ankara, Turkey

Materials and methods

We evaluated the CT images of 250 patients, who underwent pelvic CT in our hospital due to any reason between January 2018 and December 2018. A total of 26 patients were excluded from the study (19 patients had a traumatic pelvic fracture, four patients had a history of surgery related to the pelvic bones, and the remaining three patients were excluded due to the poor imaging quality). A total of 224 adult patients were included in the study (110 males; 114 females; age interval 18–84 years; mean age = 49 years) and the coccyx images of these patients were retrospectively examined. These patients had no history of complaints of coccydynia or another coccygeal disorder.

The multidetector imaging was performed with a 128-section multidetector CT scanner (Optima CT 660, General Electric, USA). The CT imaging was carried out using the parameters of 120 kV, 60–100 mA, and 0.625 mm section interval. The thin-section source images, which were obtained at the axial plane, were retrieved from PACS and examined retrospectively in all patients. All CT images were evaluated by two experienced radiologists and the reports were prepared after the consensus between them.

The multiplanar reconstruction and 3D volume rendering images of the coccyx were obtained from all patients at sagittal and coronal planes. The morphology of the coccyx, number of bone segments, the presence of scoliosis, and presence of the sacrococcygeal and intercoccygeal fusions were evaluated in all patients. Fusion was defined as continuation of anterior and posterior of cortices between adjacent vertebral bones. The sacrococcygeal and intercoccygeal angles were measured following the measurement of the length, width, and thickness of the coccyx. The intercoccygeal angle defined as the angle between the line, which was drawn parallel to the slope of the first coccygeal segment, and the line, which was drawn parallel to the slope of the distal end of the coccyx at the sagittal plane (Fig. 1a). The sacrococcygeal angle was defined as the angle between the line, which was drawn parallel to the slope of the first and second sacral vertebras, and the line, which was drawn parallel to the slope of the distal end of the coccyx (Fig. 1b).

Results

Overall, the mean length, width, and thickness of the coccyx were 40.49 ± 6.43 mm (27–62 mm), 31.5 ± 5.28 mm (20.5–61 mm), and 8.63 ± 0.99 mm (6.5–11 mm), respectively. The mean length, width, and thickness of the coccyx were 39.62 ± 6.59 mm, 30.28 ± 4.73 mm, and 8.42 ± 0.92 mm, respectively, in women; and 41.15 ± 6.17 mm, 32.56 ± 5.62 mm, and 8.82 ± 1.02 mm, respectively in men.

In our study, the morphological classification showed that 130 patients (60.7%) had type 1, 65 patients (29%) had type 2, and 17 patients (7.6%) had type 3 coccyx. In addition, five patients had an intercoccygeal angle of 0° (type 0) and one patient had retroverted coccyx (type 5) (Fig. 2). We did not detect type 4 in any of our patients (Table 1).

We evaluated also the intercoccygeal and sacrococcygeal angles according to the coccyx type in our patients. The mean intercoccygeal and sacrococcygeal angels were 35.85° ± 8.23 and 79.05° ± 11.27, respectively, in type 1 coccyx; 57.91° ± 8.09 and 58.50° ± 12.78, respectively, in

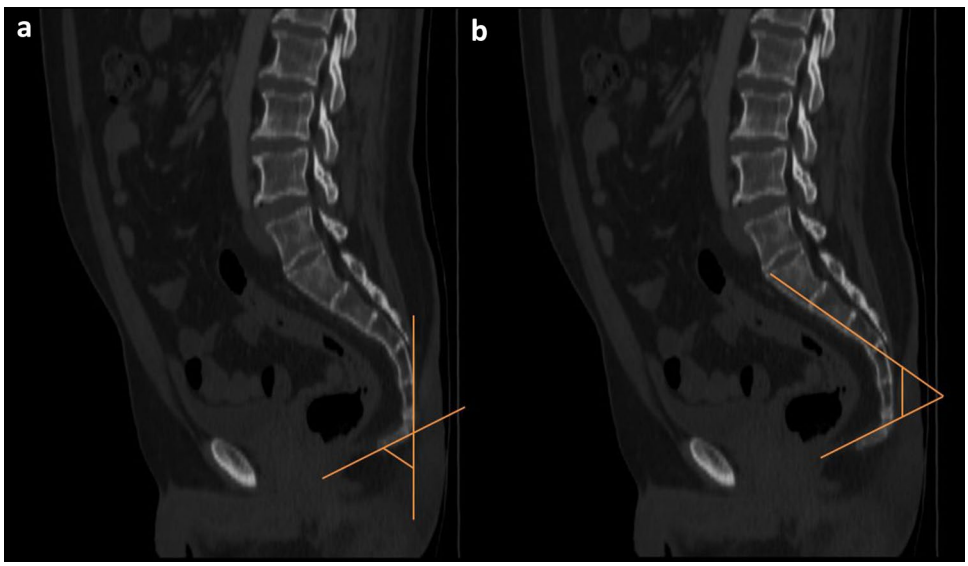

Fig. 1 Intercoccygeal vs sacrococcygeal angle measurement. **a** The angle between the line, which was drawn parallel to the slope of the first coccygeal segment, and the line, which was drawn parallel to the slope of the distal end of the coccyx at the sagittal plane, **b** The angle between the line, which was drawn parallel to the slope of the first and second sacral vertebras, and the line, which was drawn parallel to the slope of the distal end of the coccyx at the sagittal plane

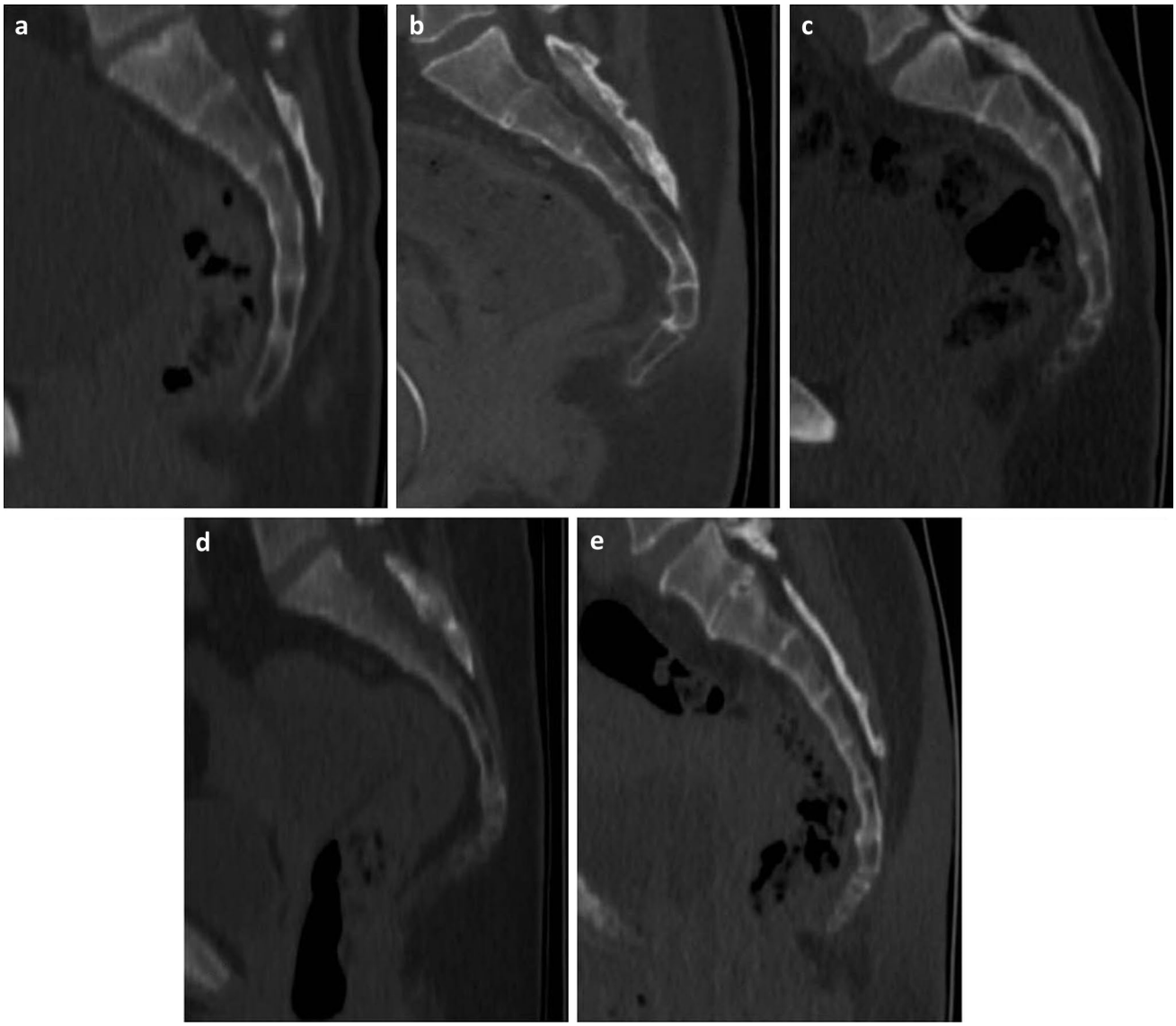

Fig. 2 The number of coccyx segments. **a** 1, **b** 2, **c** 3, **d** 4, and **e** 5

Table 1 Coccyx types

	Male	Female	Total
Type 0	3 (2.7%)	2 (1.8%)	5 (2.2%)
Type 1	60 (54.5%)	76 (66.7%)	136 (60.7%)
Type 2	37 (33.6%)	28 (27.6%)	65 (29.0%)
Type 3	10 (9.1%)	7 (6.1%)	17 (7.6%)
Type 4	0	0	0
Type 5	0	1 (0.9%)	1 (0.4%)

Table 2 Intercoccygeal and sacrococcygeal angles

	Intercoccygeal angle	Sacrococcygeal angle
Type 1	35.85 ± 8.23	79.05 ± 11.27
Type 2	57.91 ± 8.09	58.50 ± 12.78
Type 3	82.65 ± 9.95	38.19 ± 15.48
Type 0	0	116.58

type 2; and 82.65° ± 9.95 and 38.19° ± 15.48, respectively, in type 3. In addition, five patients (three males and two females) had an intercoccygeal angle of 0° and a mean sacrococcygeal angle of 116.58° ± 19.81. Finally, we determined a retroverted intercoccygeal angulation in one female patient (Table 2).

Of the participating patients, 155 (69.2%) had a four segment coccyx, 52 patients (23.2%) had 3 segment coccyx, and 15 patients (6.7%) had 5 segment coccyx. Two segment bone structure was detected in one patient (0.4%),

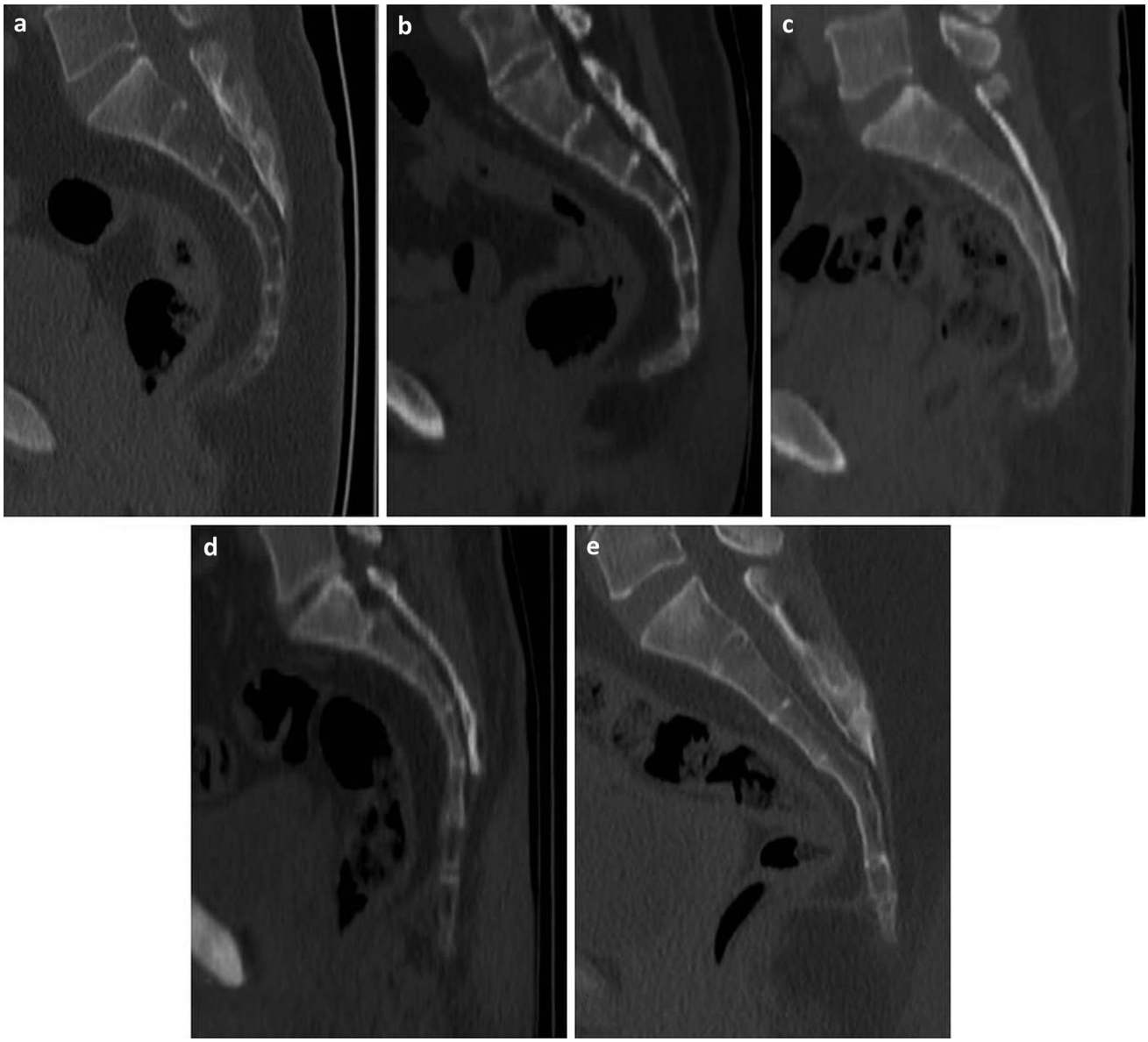

Fig. 3 Coccyx types. **a** type 1, **b** type 2, **c** type 3, **d** type 0, and **e** type 5

Table 3 Coccyx segment number

Segment number	Male	Female	Total
1	1 (0.9%)	0	1(0.4%)
2	1 (0.9%)	0	1 (0.4%)
3	22 (20.0%)	30 (26.3%)	52 (23.2%)
4	79 (71.8%)	76 (66.7%)	155 (69.2%)
5	7 (6.4%)	8 (7.0%)	15 (6.7%)

and one segment bone structure was also found in one patient (0.4%) (Fig. 3) (Table 3).

The most common fusion type was sacrococcygeal fusion and it was encountered in 152 patients. Concomitant to sacrococcygeal fusion, transverse process fusion was observed on the right side in ten patients and on the left side in six patients. Thus, a total of 16 patients had unilateral transverse process fusion. On the other hand, 44 patients had bilateral transverse process fusion concomitant to the sacrococcygeal fusion. Intercoccygeal fusion was observed in 144 patients and 118 patients had both sacrococcygeal and intercoccygeal fusions. Furthermore, a total of 17 patients had scoliosis (10 of them had scoliosis with a left curve) (Fig. 4).

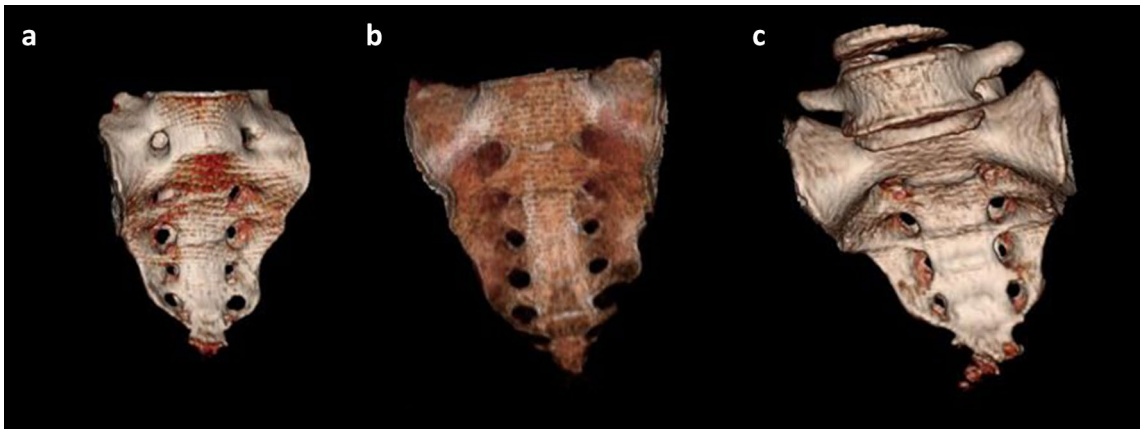

Fig. 4 **a** Sacrococcygeal, bilateral transverse process and intercoccygeal fusions, **b** sacrococcygeal, right transverse process and intercoccygeal fusions, and **c** scoliosis of the coccyx with a right curve

Discussion

Evaluation of the coccyx with X-ray may be difficult due to the technical limitations. The recent developments in the CT technology facilitated the examination of the bone structures and their relationship with the neighboring tissues. The assessment of the structures, which have angulations like coccyx, might be not possible at a single plane. A more comprehensive examination is possible with CT using post-processing tools like MPR, MIP, and 3D VR with more spatial resolution.

The classification of the coccyx was first done by Postacchini et al. A slightly forward curved is named as type 1, a more marked curved as type 2, and a sharply angled anteriorly as type 3. The subluxation of the sacrococcygeal and intercoccygeal joints is known as type 4 [9]. In our study, the most common type was type 1 ($n = 136$). Sixty-five patients had type 2 and 17 patients had type 3 coccyx. As in the study of Kerimoglu et al. [4], type 4 coccyx was also not detected in our study. Only one of our female patients had retroverted intercoccygeal angulation. Kerimoglu et al. named the retroverted angulation as type 0 [4]. However, in other studies, this retroverted angulation was named as type 5 [14]. We also preferred to name the retroverted angulation as type 5, as we determined five patients with an intercoccygeal angle of zero degree, which was never reported in the literature before. We believe that it would more correct to use the name type 0 for the coccyx, which has no intercoccygeal and sacrococcygeal angulation and extends directly to the inferior without an angulation. As these patients did not have an intercoccygeal angle, the sacrococcygeal angle has the biggest value excluding patients with retroverted angulation.

The study by Kerimoglu et al. [4] showed that the mean intercoccygeal angle in type 1, 2, and 3 was $36.67° \pm 10.56$, $56.36° \pm 10.8$, and $72.13° \pm 10.8$, respectively. These results are very close to the results in our study (Table 2). In our study, we measured the sacrococcygeal angle in addition to the intercoccygeal angle. The reason for this was to consider the sacrum and coccyx as a whole structure and the possibility of the position of the coccyx was affected by the position of the sacrum. In addition, we believed that the sacrococcygeal angle might be useful in the classification of the coccyx. According to our results, the sacrococcygeal angle declined along with the increase of the intercoccygeal angle. The smallest sacrococcygeal angle (20°) was measured in a type 3 patient.

Similar to other studies, the most common coccyx type was type 1 in our study [4, 9]. Type 2 was the second most common type. However, a study on the Korean race by Yoon et al. [14] and a study on the Polish race by Przybylski et al. [10] reported that type 2 coccyx was more common. Furthermore, studies had also shown that the number of coccyx segments might have ethnic differences. Yoon et al. stated that the different segment number in the ethnic groups may attribute to the intercoccygeal or sacrococcygeal fusion [14]. While the most common number of bone segments was three among Arabic people [6], it was four among the European and Korean people [12, 14]. In our study, the majority of the patients had four segments (69.2%), while patients with three segments constituted the second largest group (23.3%). Moreover, it was also demonstrated that the coccygeal size depended on ethnic factors. In a study, which was conducted on 50 Korean cadavers, the length of the coccyx was 3.3 cm [7], while the same length was 5.8 cm in another study conducted on the Indian male cadavers [1]. In our study, the mean coccygeal length was 4.5 cm.

The sacrococcygeal fusion was common and 29% of our patients had bilateral transverse process fusion and the features of sacralization. No fusion was observed between the first and second segments in 55 out of 144 patients with

intercoccygeal fusion and no fusion was observed between the second and third segments in seven of these patients. This finding might indicate that the event of fusion started from the distal part of coccyx. Yoon et al. reported that the age was related with the sacrococcygeal fusion in their study [14]. On the other hand, another study reported that joint fusion was not related with the age or sex [12]. Supporting this study, although we did not observe any fusion in 79-year-old female and 63-year-old male patients, we determined sacrococcygeal fusion in an 18-year-old male patient. The rate of the sacrococcygeal scoliosis was 7.6% among the participating patients in our study.

The most important disorder of the coccyx is coccydynia, which limits the physical activity to a significant extent. Coccydynia, which was first reported by Simpson, is defined as pain in the coccyx [11]. Several investigators tried to demonstrate that the coccydynia was related to the coccygeal morphology. Postacchini et al. suggested that patients with type 3 and 4 coccyx were more prone to coccydynia [9]. Besides this, Kim et al. found out that the intercoccygeal angle was significantly different in patients with idiopathic coccydynia compared to the control group [5]. Kerimoğlu et al. stated in their study that coccydynia could not be explained with the increase in the intercoccygeal angle [4]. Supporting this statement, in our study, 17 patients (7.6%), which had type 3 coccyx, did not have any complaints of coccydynia. Furthermore, it was reported that sex was also important in the development of coccydynia and women were more prone to coccydynia. The reported female:male ratio is 4:1 [3]. On the other hand, it was also demonstrated that there was no significant difference between males and females regarding the intercoccygeal angle [4, 12]. Currently, it was believed that coccydynia may depend on some factors including hormonal imbalance or other non-morphological factors [4, 13].

Our retrospective study has some limitations. The number of the patients might be insufficient for such a study about morphological evaluation. Therefore, we did not detect type 4 coccyx in any of our patients.

Conclusion

The coccyx, which is often neglected in routine pelvic CT reports, presents important interindividual differences and anatomic variations. With the help of the high spatial resolution, the anatomic visualization capacity of the multidetector CT facilitates the determination of the coccygeal variations. We conclude that the coccygeal measurements and classification, which we performed in this study, will be instructive for the radiologists and have a guiding role for the studies in the future.

In addition, we also contributed to the classification of the coccyx with this study. We determined patients with an intercoccygeal angle of zero degree, which was not mentioned in the literature before. We propose to use the term "type 0" for these patients. Thus, we believe that it would be more correct to use the term "type 5" for the coccyx, which has a retroverted angulation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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