Error Rates for Unvalidated Medical Age Assessment Procedures: Supplementary material

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This supplementary material describes results from some computations that have been done in addition to those reported in the main paper.

1 Further consequences of the posterior model

In addition to those results mentioned in the Results section of the main paper, we add some more results here, concerning prediction. In Figure 1, we have used the simulations from the posterior for the teeth and knee model parameters to compute the probability that a male of a given age will be classified as an adult using the RMV procedure.

Some particular age values may be of interest. For example, at age 17.9, the probability to be classified as an adult is 52% (credibility interval 23% – 76%), while at the exact age of 17, the probability to be classified as an adult is 28% (credibility interval 7% – 52%).

Looking instead at a person with an age randomly distributed between exactly 17 and exactly 18 (i.e., what is usually called a 17-year-old), the probaility to be classified as an adult is 41% (credibility interval 12% – 70%).

In our paper, our estimate for the probability for a child to be classified as an adult was 33%, while our estimate for the probability for an adult to be classified as a child was 7% (where both numbers concern the males classified during 2017). But both these numbers are uncertain, and it is of interest to determine whether the risk for children to be classified as adults could be smaller than the risk for adults to be classified as children. In fact, we found that, with 94% probability, the risk for children to be classified as adults was larger than the risk for adults to be classified as children.

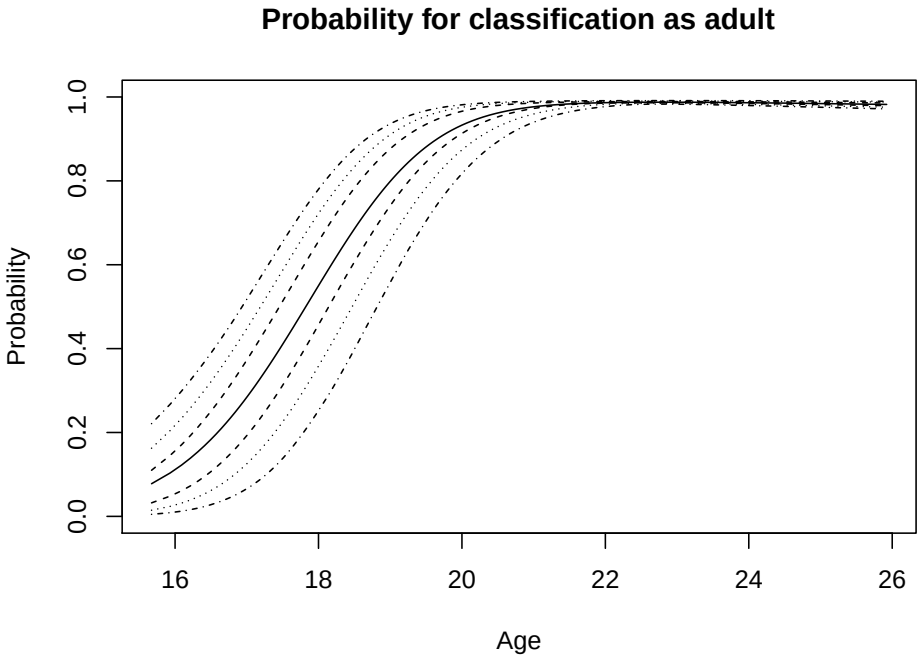

Figure 1: The posterior probability for being classified as an adult, as a function of age. The bold line represents expected probabilities. The other lines represent quantiles of simulations at proportions 0.025, 0.1, 0.25, 0.75, 0.9, and 0.975, respectively. Thus the outer lines represent a 95% credibility interval.

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	2422	541	96	3059
Teeth immature	1663	2501	198	4362
No data teeth	842	937	80	1859
SUM	4927	3979	374	9280

Table 1: Expected data under the model where age indicator model parameters are fixed at $\theta_{11} = 19.5, \theta_{12} = 1.6, \theta_{21} = 18.5$, and $\theta_{22} = 1.4$. The age population profile is fixed at the "starting point" profile of Section 2.3 of the main paper.

2 Preliminary computations with fixed parameters

As a motivation for the methodology chosen in the paper, we have done some calculations with fixed age indicator model parameters and a fixed age population profile. Specifically, we have fixed the teeth age indicator parameters θ_{11} and θ_{12} to 19.5 and 1.6, respectively, corresponding to their expected values under our T_{MAIN} prior. Correspondingly, we have fixed the knee age indicator parameters θ_{21} and θ_{22} to 18.5 and 1.4, respectively, corresponding to their expected values under our K_{MAIN} prior. We have also fixed the age population profile to the "starting point" profile specified in Section 2.3 of the main paper. We have then estimated the remaining age indicator parameters using maximum likelihood and the data of Table 1 of the main paper. The obtained results were $\theta_{13} = 0.17, \theta_{14} = -0.027, \theta_{23} = 0.034$, and $\theta_{24} = -0.005$. Finally, we have looked at whether this best-fitting model actually fits the data of Table 1.

The most likely data given the best-fitting model is shown in Table1 below. We can see that the numbers differ substantially from the actual data of Table 1 of the main paper. Could the differences be the result of chance? In fact, a Chi-square test for the hypothesis that the data of Table 1 could occur under the best-fitting model returns a p-value of less than $2.2 \cdot 19^{-16}$.

The conclusion from this is that the data of Table 1 of the main paper do contain substantial amounts of information. Not all reasonable combinations of age indicator parameters and age population profiles will fit this data. Many other combinations can be tried out using the R code we have produced, but it is more efficient to relax assumptions. We chould of course choose to relax assumptions either about the age indicator parameters or about the population profile, but this would seem unmotivated to us, as information about both is uncertain. Instead, we use prior distributions for both, as explained in the main paper.

	Classified as adults	Classified as children	Not classified	SUM
Adults	6607 (5107 – 7659)	297 (30 – 924)	55 (44 – 62)	6965 (5191 – 8590)
Children	1203 (151 – 2703)	1110 (483 – 1377)	8 (1 – 19)	2321 (690 – 4089)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	4 (0–13)	46 (3–93)	5 (0–15)	7 (0–19)
Teeth immature	41 (5–87)	83 (38–99)	49 (11–89)	57 (20–91)
No data teeth	10 (1–25)	69 (24 –97)	13 (2–30)	19 (5–35)
SUM	14 (2–33)	74 (30–98)	17 (4–35)	25 (7–44)

Table 2: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{LOW} and K_{LOW}.

	Classified as adults	Classified as children	Not classified	SUM
Adults	6796 (5282 – 7719)	369 (44 – 1100)	56 (44 – 63)	7220 (5385 – 8841)
Children	1014 (91 – 2528	1039 (307 – 1363)	7 (0 – 19)	2060 (439 – 3895)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	3 (0–12)	40 (2–91)	4 (0–14)	6 (0–17)
Teeth immature	35 (3–82)	78 (24–99)	43 (7–87)	52 (12–88)
No data teeth	9 (1–24)	64 (16 –96)	11 (0–30)	17 (3–34)
SUM	12 (1–30)	68 (19–97)	15 (2–34)	22 (5–42)

Table 3: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{MAIN} and K_{LOW}.

3 Robustness of results under perturbations of age indicator prior

In this section, we reproduce Tables 3 and 4 in the main paper for sets of different combinations of priors. Referring to the priors defined in Section 2.2 of the main paper, Tables 2 through 9 report results for all combinations of the three priors T_{LOW}, T_{MAIN}, and T_{HIGH} with the three priors $K_{\text{LOW}}, K_{\text{MAIN}}$, and K_{HIGH} except the combination T_{MAIN} and K_{MAIN}, which is the case reported in the main paper. Finally, Table 10 reports results when combining T_{HAGLUND} with K_{MAIN}, where T_{HAGLUND} is a prior centered on the values 20.9 and 2.5 instead of the values 19.5 and 1.6 used in the T_{MAIN} prior. Finally, Table 11 shows how sensitivity and specificity varies under perturbations of the priors. Under the T_{HAGLUND} and K_{MAIN} priors, the sensitivity is 93% (86–98) and the specificity is 72% (46-93).

	Classified as adults	Classified as children	Not classified	SUM
Adults	7165 (5636 – 7789)	573 (79 – 1306)	58 (47 – 63)	7796 (5779 – 9143)
Children	645 (21 – 2174)	834 (101 – 1328)	5 (0 – 16)	1484 (137 – 3501)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	2 (0–9)	26 (0–84)	2 (0–11)	4 (0–14)
Teeth immature	23 (1–72)	64 (8–97)	31 (2–77)	39 (4–81)
No data teeth	5 (0–20)	49 (5–92)	8 (0–25)	12 (1–30)
SUM	8 (0–26)	54 (6–93)	10 (1–29)	16 (1–38)

Table 4: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{HIGH} and K_{LOW}.

	Classified as adults	Classified as children	Not classified	SUM
Adults	6934 (5317 – 7762)	402 (50 – 1212)	57 (46 – 63)	7393 (5425 – 9011)
Children	876 (48 – 2493)	1005 (195 – 1357)	6 (0 – 17)	1887 (269 – 3855)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	3 (0–12)	37 (1–89)	3 (0–13)	5 (0–17)
Teeth immature	30 (2–81)	76 (15–98)	38 (5–89)	48 (8–87)
No data teeth	7 (0–23)	60 (9 –95)	10 (0–27)	15 (2–33)
SUM	10 (1–30)	66 (12–95)	13 (2–33)	20 (3–42)

Table 5: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{LOW} and K_{MAIN}.

	Classified as adults	Classified as children	Not classified	SUM
Adults	7451 (6343 – 7803)	717 (170 – 1353)	60 (52 – 63)	8229 (6598 – 9213)
Children	359 (7 – 1467)	690 (54 – 1237)	3 (0 – 11)	1051 (67 – 2682)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	1 (0–5)	16 (0–68)	1 (0–6)	2 (0–10)
Teeth immature	13 (0–51)	54 (4–92)	21 (0–58)	29 (2–65)
No data teeth	3 (0–13)	38 (2 –82)	5 (0–17)	8 (0–22)
SUM	4 (0–17)	43 (3–85)	7 (0–20)	11 (1–29)

Table 6: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{HIGH} and K_{MAIN}.

	Classified as adults	Classified as children	Not classified	SUM
Adults	7238 (5852 – 7782)	501 (90 – 1215)	58 (49 – 63)	7798 (6010 – 9035)
Children	572 (24 – 1958)	906 (192 – 1317)	5 (0 – 14)	1482 (245 – 3270)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	2 (0–8)	29 (1–81)	2 (0–10)	4 (0–13)
Teeth immature	19 (1–64)	70 (15–97)	29 (4–70)	38 (7–76)
No data teeth	5 (0–18)	53 (9 –91)	7 (0–22)	12 (2–28)
SUM	6 (0–23)	59 (12–92)	10 (1–26)	16 (3–35)

Table 7: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{LOW} and K_{HIGH}.

	Classified as adults	Classified as children	Not classified	SUM
Adults	7454 (6422 – 7802)	666 (160 – 1325)	60 (52 – 63)	8179 (6663 – 9177)
Children	356 (8 – 1388)	741 (82 – 1247)	3 (0 – 11)	1101 (103 – 2617)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	1 (0–5)	18 (0–67)	1 (0–6)	2 (0–9)
Teeth immature	13 (0–48)	58 (7–93)	21 (1–57)	30 (3–64)
No data teeth	3 (0–12)	41 (4 –83)	5 (0–17)	8 (1–22)
SUM	4 (0–16)	47 (5–85)	7 (0–20)	12 (1–28)

Table 8: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{MAIN} and K_{HIGH}.

	Classified as adults	Classified as children	Not classified	SUM
Adults	7610 (6858 – 7808)	803 (253 – 1362)	61 (55 – 63)	8473 (7229 – 9226)
Children	200 (2 – 952)	604 (45 –1154)	2 (0 – 8)	807 (54 – 2051)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	0 (0–3)	11 (0–53)	1 (0–4)	1 (0–6)
Teeth immature	7 (0–33)	47 (4–88)	15 (0–43)	22 (2–52)
No data teeth	2 (0–8)	32 (2 –73)	3 (0–13)	6 (0–17)
SUM	2 (0–11)	38 (3–77)	5 (0–15)	9 (1–22)

Table 9: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{HIGH} and K_{HIGH}.

	Classified as adults	Classified as children	Not classified	SUM
Adults	7405 (6414 – 7793)	583 (123 –1294)	60 (52 –63)	8048 (6630 – 9138)
Children	405 (17 – 1369)	824 (113 –1284)	3 (0 – 11)	1232 (142 – 2650)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	1 (0–5)	32 (1–83)	2 (0–7)	3 (0–11)
Teeth immature	12 (0–44)	63 (9–95)	21 (1–53)	31 (4–62)
No data teeth	3 (0–12)	50 (5–90)	5 (0–17)	10 (1–22)
SUM	4 (0–16)	55 (7–92)	7 (1–20)	13 (2–29)

Table 10: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{HAGLUND} and K_{MAIN}.

	Sensitivity			Specificity		
	K_{LOW}	K_{MAIN}	K_{HIGH}	K_{LOW}	K_{MAIN}	K_{HIGH}
T_{LOW}	96 (89–99)	95 (86–99)	94 (86–99)	52 (34–80)	59 (35–87)	67 (40–94)
T_{MAIN}	95 (87–99)	93 (86–98)	92 (85–98)	55 (35–83)	67 (39–94)	73 (46–97)
T_{HIGH}	93 (86–99)	91 (85–97)	91 (85–97)	63 (37–92)	72 (44–95)	80 (52–99)

Table 11: The dependence of sensitivity and specificity on choices of priors. Results for our main priors are in the centers of the tables; other results are for various combinations of the priors $T_{\text{LOW}}, T_{\text{MAIN}}$, and T_{HIGH} for teeth and $K_{\text{LOW}}, K_{\text{MAIN}}$, and K_{HIGH} for knees. The parentheses contain 95% credibility intervals.

	Classified as adults	Classified as children	Not classified	SUM
Adults	7389 (5284 – 7810)	812 (49 –1407)	60 (46 –63)	8261 (5385–9280)
Children	421 (0 – 2526)	595 (0 –1358)	3 (0 – 17)	1019 (0–3895)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	1 (0–10)	16 (0–89)	2 (0–12)	2 (0–16)
Teeth immature	15 (0–84)	46 (0–98)	22 (0–88)	27 (0-89)
No data teeth	4 (0–23)	34 (0 –95)	5 (0–27)	8 (0–33)
SUM	5 (0–30)	38 (0–95)	7 (0–33)	11 (0–42)

Table 12: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{MAIN} and K_{MAIN}, and at the same time a normally distributed prior for the age population profile (see the text).

	Classified as adults	Classified as children	Not classified	SUM
Adults	7457 (5852 – 7808)	686 (93 –1354)	60 (49 –63)	8203 (6012–9218)
Children	353 (2 – 1958)	721 (53 –1314)	3 (0 – 14)	1077 (62 –3268)
SUM	7810	1407	63	9280

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	1 (0–8)	16 (0–80)	1 (0–10)	2 (0–13)
Teeth immature	12 (0–64)	56 (4–96)	22 (0–71)	29 (2-76)
No data teeth	3 (0–17)	40 (2 –90)	5 (0–22)	8 (0–28)
SUM	4 (0–23)	45 (3–92)	7 (0–27)	12 (1–35)

Table 13: Results corresponding to Tables 3 and 4 of the main paper when using the priors T_{MAIN} and K_{MAIN}, and at the same time a uniform prior for the age population profile (see the text).

4 Robustness of results under perturbations of age population profile prior

Finally, in Tables 12 and 13 we reproduce Tables 3 and 4 in the main paper using priors T_{MAIN} and K_{MAIN} but using two variants of the population prior. In Table 12, we use a normal distribution with expectation 22.5 and standard deviation 4, truncated to the interval $[15, 30]$. The sensitivity becomes 91% (85–99) and the specificity 72% (34–100). In Table 13, we use a uniform distribution on the interval $[15, 25]$. The sensitivity becomes 92% (85–98) and the specificity 76%(40–99).

	Knees mature	Knees immature	No data knees	SUM
Teeth mature	190	1	6	197
Teeth immature	79	12	5	96
No data teeth	40	1	3	44
SUM	309	14	14	337

Table 14: The data for females

5 Female data

The RMV results for tested females during 2017 are given in Table 14. As the numbers are quite small compared to the counts for males and thus contain less information, we have so far not carried out an analysis of these numbers.