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SUPPLEMENTARY ONLINE MATERIAL FOR

Evolution and identity of synapsid carpal bones

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Published in *Acta Palaeontologica Polonica* 2020 65 (4): 649-678.
https://doi.org/10.4202/app.00709.2019

Supplementary Online Material

SUPPLEMENTARY INFORMATION

Supplementary information 1: carpals, sesamoids and prepollices

Manus: In the manus, the skeletal elements are grouped in three main segments aligned in a proximodistal direction. The **carpus** or **basipodium**, with its polyhedral **carpals**, is the basal part of the manus, connected proximally to the radius and ulna by the wrist joint. Distally it is followed by the **metacarpus**, composed of the **metacarpals** as its skeletal elements and then the digits, each consisting of several **phalanges**. The carpus together with the metacarpus forms the **palm**, each metacarpal together with the corresponding digit comprises the manual **rays** (Biesecker et al. 2009).

Carpus: The carpal elements are polyhedral with no shaft. These elements comprise carpal bones (carpals) and usually sesamoids and prepollices (see below). Most of the carpals are tightly intercalated and their connecting joints have a limited mobility range, so that the whole carpus is quite immobile. Carpal elements originate from single or complex cartilaginous primordia. The skeleton of the carpus usually ossifies, although some elements may remain cartilaginous. The ossification of the basipodium takes place after the ossification of the diaphyses of the long bones, including the ray elements (de Oliveira 1998, Gilsanz and Ratib 2005).
The carpal elements may be a single element or composed of several fused elements. Single elements are multifaceted (polyhedral), quite equidimensional (short), with articular lateral surfaces, and the ventral face with apophyses, crests, protuberances for muscle attachments. The presence of fusion lines or irregular shapes with set-back angles reveals the complex origin of composed elements.

Scheme of the carpals:

Proximal row:	radiale (scaphoid), intermedium, ulnare (triquetrum), pisiform
proximal/central row:	lateral centrale/lunate
central row:	(medial) centrale
distal row:	distal carpal I (trapezium), distal carpal II (trapezoid), distal carpal III (capitate), distal carpal IV, distal carpal V (IV ±V = hamate)

Sesamoids: Sesamoids are periarticular skeletal elements, which initially form in juxtaposition to or independently of bones and joints. They are commonly related to tendons and ligaments, have a genetic basis and, once they are formed, epigenetic stimuli drive their growth and development to the acquisition of their definitive tissue composition, which can be diverse, for example, cartilage, fibrocartilage, or bone (Haines 1969, Amador et al. 2018, Abdala et al. 2019). Although they frequently appear associated with the tendon system of the limbs, there are also sesamoids associated with the tendinous system of other joints of the body. The number and position of sesamoids varies within different groups of tetrapods as well as between different tetrapod lineages (Vickaryous and Olson 2007). Some sesamoids are common and well documented e.g. the patella, which appears in almost all tetrapod taxa (Samuels et al. 2017; Abdala et al. 2017). As sesamoids are embedded in tendons, they may be easily lost along with the soft tissues during fossilization.

Periarticular ossicles (Lunulae): Lunulae are skeletal elements associated with joints. They may be superficially associated or lie within the joint cavities inside the joint capsule, but do not initiate their development within a tendon (Vickaryous amd Olson 2007). They may remain cartilaginous but occasionally mineralize. Preservation of these elements in fossils is not common because of their cartilaginous nature or location within soft tissue, which may be lost during fossilization, especially when limbs are disarticulated.

Pisiform: The pisiform is a skeletal element contiguous with the lateral/ventral surface of the proximal part of the ulnare (reviewed in Abdala et al., 2019). It is highly conserved and associated with the amniote carpus (Carroll and Currie 1991). Shubin and Alberch (1986) described the pisiform as a *de novo* condensation in ontogeny, but in the opinion of some early authors, it is a vestigial ancestral bone (postminimus; Gillies 1929). Kivell (2016) also proposed that its pattern of development did not resemble that of a sesamoid. Recently, Diaz and Trainor (2015) published data on three genera of Chamaeleonidae showing that the pisiform arises as a segmentation of the ulnare, supporting its identity as a carpal bone. Among mammals, the pisiform is often considered to be a carpal bone (e.g. Kjosness et al. 2014 and Reno et al. 2016). Other authors recognized it as a sesamoid (Haines 1969, Prochel and Sánchez-Villagra 2003, Fabrezi et al., 2007, Fontanarrosa and Abdala 2014, 2016). Their arguments are (i) that it is associated to the tendon of the flexor carpi ulnaris, (ii) that its ossification starts late and (iii) that it has a slightly ventral position with respect to the other carpal bones.

Prepollex: A prepollex is a distal set of nodular aligned elements situated on the medial side of the manus. In contrast to the phalanges of the other digits, the segments of the prepollex derive ontogenetically from the medial side, the radius and radiale (Gregory et al. 1923, Shubin and Alberch 1986). A prepollex can appear digit-like, but the single segment does not possess epiphyses. The segments of a prepollex may remain cartilaginous, or can calcify or ossify. Skeletal elements designated as prepollices exist in several tetrapod taxa, e.g. some reptiles (Wagner et al. 2000), birds (Starck 1979) and in many mammals (e.g. Lewis 1989, Gillies and Hopkins 1922, Bardeleben 1894, Stafford and Thorington 1998, de Oliveira et al. 1998, Weissengruber et al. 2006, Weisbecker and Sánchez Villagra 2006, Lemelin et al. 2008, Schwermann and Martin 2012, Echeverria et al. 2019). The named "prepollex" in mammals is often identified as an os falciforme or a radial sesamoid (e.g. Wood-Jones 1939, Endo et al. 1999, Salesa et al. 2006, Nauck 1933 in Sánchez-Villagra and Menke 2005, Vickaryous and Olson 2007, Amador et al. 2018, Echeverria et al. 2019). Because of this ambiguity in the identity of mammalian prepollices and the difficulties in distinguishing between prepollices and sesamoids in fossil synapsids, we designate these bones in synapsids with the term **prepollex/sesamoid**.
A prepollex/sesamoid is present in all mammalian orders with five functional digits (Bardeleben 1889). They are found in the three major groups of modern mammals: monotremes (Vogelnest and Allan 2015), marsupials (Weisbecker and Sánchez-Villagra 2006) and most placental mammals (Vickaryous and Olson 2007, Bardeleben 1894, Amador 2018). Usually one prepollex/sesamoid segment is present, seldom two (Weisbecker and Sánchez-Villagra 2006). The prepollex/sesamoid can have variable positions in mammals. It is present mostly on the radiale, but sometimes on the distal carpal I or on the medial side of distal carpal I. Occasionally, it appears on the styloid process of the radiale (Bardeleben 1894, Holmgren 1952, Amador et al. 2018, Sánchez-Villagra and Menke 2005). Salton and Sargis (2008) emphasis the importance of its extension in the palmar direction on

the medial side of the midcarpal joint. In extant mammals, it is unusual for a prepollex/sesamoid to be completely integrated into the carpus. Usually it is situated at the medial border, with a free ending in medial or distal direction. In some cases, the prepollex/sesamoid shows evident functions as in elephants where it is a cartilaginous medial element supporting the metacarpal compartment of the cushion, to distribute forces during walking (Weissengruber et al. 2006); or the hypertrophied prepollex in talpids (Sánchez-Villagra and Menke, 2005).

The early embryological development of the mammalian prepollex/sesamoid supports the hypothesis that it is a true carpal bone, because the histological sections of the embryos of *Monodelphis*, *Caluromys* and *Talpa* do not show differences in condensation and chondrification with respect to the other carpals, other than the late onset of ossification (Prochel and Sánchez-Villagra 2003). In *Talpa*, however, electron microscopy reveals similarities of the profound region with a calcified tendon, whereas the superficial portion resembles genuine bone (Prochel 2006). In several cases, the sesamoid character of the mammalian prepollices could be deduced from their late ossification and their connection to a tendon (e.g. Prochel and Sánchez-Villagra 2003, Prochel 2006).

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Supplementary Tables S1-S10

Table S1: Shape, position and contacts of the radiale. **Abbreviations**: **ce** centrale, **di** distal carpal/distal carpals, **dist** distal, **f** fused, **int** intermedium, **la** lateral, **lce** lateral centrale, **li** little, **lu** lunate, **mce** medial centrale, **me** medial, **ra** radius, **recta** rectangular, **rl** radiale, **p** part, **p/s** prepollex/sesamoid, **sp** space, **tria** triangular. * Radius absent; distal contact of radius judged from carpal joint facies.

Table S1	view	radiale	radius	radiale	radiale	radiale	radiale
radiale	of	shape	dist	dist-me	dist	dist-la	la
taxon	fossil	a	b	c	d	e	f
CASEIDAE							
Euromycter MNHN.F.MCL-2	do	recta transverse	rl	li sp: dist-me of rl	mce, di I?		lce
(Sigogneau-Russell and Russell 1974)							
Cotylorhynchus OMNH 00655 (Stovall et al. 1966)	do	recta to square	rl*	di I, li sp: rl-di I	di I, mce		lce, part of int
"EUPELYCOSAURIA"							
Ophiacodon FMNH UC 458	do	recta transverse	rl*	sp: rl-di I	mce	lce	dist half int
Ophiacodon MCZ 1203	do	recta transverse	rl*		mce	lce	dist half int
Ophiacodon FMNH UC 671	do	recta transverse	rl	sp: rl-di I	mce	lce?	dist half int
Edaphosaurus NHMUK R 9204 (cast)	do	recta transverse	rl*	mce	mce		lce
Sphenacodon CM 76895 (Henrici et al. 2005)	do	pentagonal	rl*	mce	mce	lce	dist half int
Dimetrodon MCZ 1365 (cast)	do	pentagonal	rl*	mce	mce	lce	dist int
BIARMOSUCHIA							
Biarmosuchidea indet. PIN 1758/320	do	recta to pentagonal	rl	mce	mce	lce	int
Hipposaurus SAM-PK-9081	do	square	rl	sp: rl-mce-di I	mce	lce	dist two third int
DINOCEPHALIA							
Titanophoneus PIN 157/1	do	pentagonal	rl	mce		lce	dist tree third int
Estemmenosuchus PIN 1758/23	do	triangle to pentagonal	rl	mce		lce	int
ANOMODONTIA							
Suminia PIN 2212/62 (Fröbisch & Reisz 2011)	ve	square	rl	sp: rl-di I?	mce	lce	lce, dist half int
Galechirus SAM-PK-1068	do	recta to pentagonal	rl		mce	lce	dist half int
Galechirus AMNH 5516							
Eosimops BP/1/6674	ve	recta transverse	rl	sp: rl-di I	mce	lce	dist half int
Robertia SAM-PK-11885a	do	recta to square	rl	sp: rl-di I	mce		
Robertia SAM-PK-11885b	ve		rl		mce		dist half int
Diictodon CGS FL186	do	oval transverse	rl	sp: rl-di I	mce	lce	dist half int
Diictodon TM4991	do	oval to tria	rl	sp: rl-di I, mce	mce	lce	dist half int
Diictodon UMZC T 420							
Diictodon GPIT/RE/7193	do	recta to square	rl	sp: ra!-di I	mce		lce, dist part int
Diictodon SAM-PK-K10699	do	recta to trapezoidal	?	sp: rl-di I	mce		lce, dist half int
Diictodon CGS RMS214	ve	trapezoidal	rl	sp: rl-di I	mce	lce	dist part int
Diictodon CGS T72	ve	recta transverse	?	sp: rl-di I	mce	lce	dist half int
Cistecephalus BP/1/2124	do	recta transverse, oblique	rl	di I	mce, di III		lce
Cistecephalus BP/1/2915	ve	recta transverse	rl		mce		lce
Kannemeyeria NHMUK R 3741	do	oval to pentagonal	rl		mce or di II	lce	dist half int
Stahleckeria MCZ 1688	do	oval to pentagonal	rl	di I	di I and lce	lce	int
GORGONOPSIA							
Arctognathus SAM-PK-3329	do	oval to pentagonal		mce f to rl, little sp		lce f to rl	
Aelurognathus SAM-PK-2342	do	recta to pentagonal	rl	sp: rl-di I	mce	lce	
cf. *Cynariops* SAM-PK-K10000	ve	oval to pentagonal		sp: rl-di I	mce	lce	
Dinogorgon BP/1/2190	ve	oval to rectangular	rl		mce	lce	dist half int
Gorgonopsia indet. BP/1/1210	do	oval to triangular	rl	mce, sp: rl-di I	mce	lce	dist part int
THEROCEPHALIA							
Glanosuchus SAM-PK-K7809	do	trapezoidal to square	rl	li sp: rl-di I	mce	lce	dist part int
Glanosuchus SAM-PK-12051	do	recta to pentagonal	rl*	mce	mce	lce	int
Glanosuchus CGS RS424	do	pentagonal	rl*	mce	mce	lce	int
Olivierosuchus BP/1/3973	ve	oval to trapezoidal	rl	big sp		lce	dist part int
Olivierosuchus BP/1/3849							
Theriognathus NHMUK R 5694	do	oval to pentagonal	rl*	two mce, sp	two mce	lce	int
Ictidosuchoides CGS CM86-655	do	pentagonal to trapezoidal	rl	mce	mce	lce	int
?Ictidosuchoides BP/1/2294	do	pentagonal	rl	mce	mce	lce	
Tetracynodon AM 3677	do	square		mce	mce		lce, int?
Microgomphodon SAM-PK-K10160	ve	recta	rl	big sp		lce	
NON-MAMMALIAMORPH CYNODONTIA							
Procynosuchus BP/1/591	do	trapezoidal	rl		mce		lce, dist part int
Procynosuchus NHMUK PV R 37054	do	square	rl*	sp: rl-di I	mce		lce, dist part int
Procynosuchus RC92	do	square	rl	sp: rl-di I	mce		lce
Galesaurus BP/1/2513	do	recta transverse	rl	li sp: rl-di I	mce		lce, dist part int
Galesaurus SAM-PK-K10465	do	oval to trapezoidal	rl	li sp: rl-di I	mce		lce (very big)

Thrinaxodon BP/1/1737	ve	recta transverse	rl		mce f to rl?		lce
Thrinaxodon BP/1/7199	do	recta to square	rl	li sp	mce		lce, dist half int
Diademodon NHMUK R-3581	do	recta transverse	rl		mce		lce (very big)
Diademodon USNM 23352	do	square	rl	li sp	mce		lce, dist half int
Cynognathia indet. BP/1/4534	do	square	rl		mce f to rl(?)		lce
Exaeretodon PVL 2554	do	recta transverse	rl	sp: rl-di I	mce		lce
Trucidocynodon UFRGS PV-1051T	do	square	rl		mce		lce, dist half int
MAMMALIAMORPHA							
Tritylodontidae indet. WCW-06A-34	do	tria to recta	rl, lu	di I	ce	ce	lu
Bienotheroides IVPP V 7905	do	tria to recta	rl, lu	di I	ce f to rl	ce	lu
Kayentatherium TMM 43690-5.136 (Hoffmann & Rowe 2018)	do	trapezoidal		sp: rl-di I	ce		
Jeholodens GMV 2139a	do	recta to tria	rl, lu	di I	ce		lu
Zhangheotherium IVPP V7466	do	recta transverse, short	rl, lu	nodule (p/s?)	ce		lu
Eomaia CAGS01-IG-1a	do	recta transverse, short	rl, lu				lu

Table S2: Shape, position and contacts of the intermedium. **Abbreviations**: **dist** distal, **hourgl** hourglass-shaped, **int** intermedium, **irr** irregular, **lce** lateral centrale, **me** medial, **pr** proximal, **ra** radius, **recta** rectangular, **rl** radiale, **sh** shaped. * Ulna absent; distal contact of ulna judged from carpal joint facies. ** Proportion judged from photos (in caseids and *Suminia* from figures).

Table S2 **intermedium** **taxon**	**view** **of** **bone**	**int** **shape** **a**	**ulna** **dist-me** **b**	**int** **dist** **c**	**int** **me** **d**	**int length** **in relation to rl**** **e**
CASEIDAE						
Euromycter rutenus MNHN.F.MCL-2 (Sigogneau-Russell and Russell 1974)	do	square		lce	ra	longer
Cotylorhynchus romeri OMNH 00655 (Stovall et al. 1966)	do	pentagonal to irr subcircular		lce, rl partly	ra	about the same length
"EUPELYCOSAURIA"						
Ophiacodon retroversus FMNH UC 458	do	recta, dist-pr	int*	lce	rl, ra	longer
Ophiacodon retroversus MCZ 1203	do	square	int*	lce	rl, ra	about the same length
Ophiacodon mirus FMNH UC 671	do	recta, dist-pr	int	lce	rl, ra	longer
*Edaphosaurus boanerges*NHMUK R 9204 (cast)	do			lce	ra	
Sphenacodon ferox CM 76895 (Henrici et al. 2005)	do	pentagonal	int*	lce	rl, ra	
Dimetrodon milleri MCZ 1365 (cast)	do	pentagonal		lce	rl, ra	
BIARMOSUCHIA						
Biarmosuchidea indet. PIN 1758/320	do	recta to hourgl, slender	int	lce	rl	shorter
Hipposaurus major SAM-PK-9081	do	recta dist-pr, slender	int	lce	rl, ra	shorter
DINOCEPHALIA						
Titanophoneus potens PIN 157/1	do	recta dist-pr, slender		lce	rl, ra	shorter
Estemmenosuchus uralensis PIN 1758/23	me	ovoid, ~me view		lce	rl	shorter
ANOMODONTIA						
Suminia getmanovi PIN 2212/62 (Fröbisch & Reisz 2011)	ve	recta dist-pr, slender	int	lce	rl, ra	shorter
Galechirus scholtzi SAM-PK-1068	do	recta dist-pr, slender	int	lce	rl, ra	about the same length
Galechirus scholtzi AMNH 5516	do	recta dist-pr, slender				
Eosimops newtoni BP/1/6674	ve	recta dist-pr, slender		lce	rl, ra	
Robertia broomiana SAM-PK-11885a						
Robertia broomiana SAM-PK-11885b	ve	recta dist-pr, slender	int	lce	rl, ra	
Diictodon feliceps CGS FL186	do	recta dist-pr, slender	int	lce	rl, ra	longer
Diictodon feliceps TM4991	do	recta dist-pr, slender	int	lce	rl, ra	about the same length
Diictodon feliceps UMZC T 420	me	square, ~me view				
Diictodon feliceps GPIT/RE/7193	do	recta dist-pr, slender	int	lce	rl, ra	about the same length
Diictodon feliceps SAM-PK-K10699	me	square, ~me view	int	lce	rl, ra	about the same length
Diictodon feliceps CGS RMS214	me	ovoid, ~me view	int		rl, ra	
Diictodon feliceps CGS T72	ve	ovoid, ve view		lce	rl, ra	
Cistecephalus microrhinus BP/1/2124	do	recta to hourgl	int	lce	ra?	
Cistecephalus microrhinus BP/1/2915	ve	recta to hourgl, ve view	int		ra?	
Kannemeyeria simocephalus NHMUK R 3741	do	sicle-sh	int	lce	rl, ra	about the same length
Stahleckeria potens MCZ 1688	do	recta to hourgl		lce	rl	shorter
GORGONOPSIA						
Arctognathus curvimola SAM-PK-3329						
Aelurognathus tigriceps SAM-PK-2342						
cf. *Cynariops robustus* SAM-PK-K10000						
Dinogorgon rubidgei BP/1/2190	ve		int	lce	rl, ra	much shorter
Gorgonopsia indet. BP/1/1210	do			lce	rl, ra?	
THEROCEPHALIA						
Glanosuchus macrops SAM-PK-K7809	do	recta to hourgl, slender	int	lce	rl, ra	shorter
Glanosuchus macrops SAM-PK-12051	do	recta, slender		lce	rl	much shorter
Glanosuchus macrops CGS RS424	do			lce	rl	much shorter

Olivierosuchus parringtoni BP/1/3973	ve	recta, slender	int	lce	rl, ra	
Olivierosuchus parringtoni BP/1/3849						
Theriognathus microps NHMUK R 5694	do	recta to ovoid, slender		lce	rl	much shorter
Ictidosuchoides longiceps CGS CM86-655	do	recta to hourgl, slender	int	lce	rl	shorter
?Ictidosuchoides longiceps BP/1/2294	do		int			
Tetracynodon darti AM 3677	do			lce		
Microgomphodon oligocynus SAM-PK-K10160	ve		int?			
NON-MAMMALIAMORPH CYNODONTIA						
Procynosuchus delaharpeae BP/1/591	do	recta	int	lce	rl, ra	
Procynosuchus delaharpeae NHMUK PV R 37054	do	ovoid, irr	int*	lce	rl, ra	shorter
Procynosuchus delaharpeae RC92	me	recta, irr, ~me view	int	lce	ra	about the same length
Galesaurus planiceps BP/1/2513	do	bean to sicle-sh	int	lce	rl, space, ra?	about the same length
Galesaurus planiceps SAM-PK-K10465	do	recta, prox round	int	lce	space, ra	about the same length
Thrinaxodon liorhinus BP/1/1737	ve	recta	int			
Thrinaxodon liorhinus BP/1/7199	do	recta	int		rl, ra	shorter
Diademodon tetragonus NHMUK R-3581	do		int	lce		
Diademodon tetragonus USNM 23352	do		int	lce	rl, ra	much shorter
Cynognathia indet. BP/1/4534	do		int			
Exaeretodon argentinus PVL 2554	do	recta to hourgl, slender	int	lce	ra	about the same length
Trucidocynodon riograndensis UFRGS PV-1051T	do	recta to hourgl	int?*	lce	rl, ra	shorter
MAMMALIAMORPHA						
Tritylodontidae indet. WCW-06A-34						
Bienotheroides wanhsienensis IVPP V 7905						
Kayentatherium wellesi TMM 43690-5.136 (Hoffmann & Rowe 2018)						
Jeholodens jenkinsi GMV 2139a						
Zhangheotherium quinquecuspidens IVPP V7466						
Eomaia scansoria CAGS01-IG-1a						

Table S3(1): Shape and relative length of the ulnare. **Abbreviations**: **dist** distal, **hourgl** hourglass-shaped, **irr** irregular, **mc** metacarpal, **me** medial, **pr** proximal, **recta** rectangular. Numbers in italics are approximations based on measurements from photographs (in caseids from figures).

Table S3(1) ulnare taxon	view of fossil	ulnare shape a	length of ulnare mm	length of mcIII mm	length of ulnare as % of mcIII b
CASEIDAE					
Euromycter MNHN.F.MCL-2	do	recta			*127*
(Sigogneau-Russell and Russell 1974)					
Cotylorhynchus OMNH 00655 (Stovall et al. 1966)	do	ovoid, pr-dist			*188*
"EUPELYCOSAURIA"					
Ophiacodon FMNH UC 458	do	recta, me side concave			
Ophiacodon MCZ 1203	do	recta, me side concave	34,3	37,1	92
Ophiacodon FMNH UC 671	do	recta, me side concave			*85*
Edaphosaurus NHMUK R 9204 (cast)	do	ovoid, pr-dist	30,5	35,6	86
Sphenacodon CM 76895 (Henrici et al. 2005)	do	recta, me side concave			
Dimetrodon milleri MCZ 1365 (cast)	do	elongated, pr round, dist recta			
BIARMOSUCHIA					
Biarmosuchidea indet. PIN 1758/320	do	recta, me side concave	28,1	45,1	62
Hipposaurus SAM-PK-9081	do	recta, me side concave			*58*
DINOCEPHALIA					
Titanophoneus PIN 157/1	do	recta, me side concave	47,4	47,3	100
Estemmenosuchus PIN 1758/23	do	recta	89,3	51,8	172
ANOMODONTIA					
Suminia PIN 2212/62 (Fröbisch & Reisz 2011)	ve	recta			
Galechirus SAM-PK-1068	do	recta, me side concave	3,6	8,8	41
Galechirus AMNH 5516	do		4,5	12,0	38
Eosimops BP/1/6674	ve		9,9	10,4	95
Robertia SAM-PK-11885a	do	recta			
Robertia SAM-PK-11885b	ve	recta, me side concave			
Diictodon CGS FL186	do	recta, me side concave	6,3	9,6	66
Diictodon TM4991	do	recta to ovoid			
Diictodon UMZC T 420	ve		6,6	10,0	66
Diictodon GPIT/RE/7193	do		7,3	9,9	74
Diictodon SAM-PK-K10699	do	recta, me side concave	5,6	11,3	50
Diictodon CGS RMS214	ve		6,9	10,0	69
Diictodon CGS T72	ve	recta, me side concave	7,4	9,8	76
Cistecephalus BP/1/2124	do	recta, me side concave	3,8	7,7	49
Cistecephalus BP/1/2915	ve	semi-recta	3,8	5,2	73

Kannemeyeria NHMUK R 3741	do	incomplete?			
Stahleckeria MCZ 1688	do	recta	93,0	71,2	131
GORGONOPSIA					
Arctognathus SAM-PK-3329	do				
Aelurognathus SAM-PK-2342	do	semi-recta, me side concave	44,2	43,5	102
cf. *Cynariops* SAM-PK-K10000	ve		16,3	25,9	63
Dinogorgon BP/1/2190	ve	recta	30,0	36,0	83
Gorgonopsia indet. BP/1/1210	do	recta, me side concave	43,2	48,2	90
THEROCEPHALIA					
Glanosuchus SAM-PK-K7809	do	hourgl	24,4	16,3	150
Glanosuchus SAM-PK-12051	do	hourgl			
Glanosuchus CGS RS424	do	hourgl	27,4	21,9	125
*Olivierosuchus*BP/1/3973	ve	recta, me side concave	8,2	14,2	58
Olivierosuchus BP/1/3849	do		10,5	12,7	83
Theriognathus NHMUK R 5694					
Ictidosuchoides CGS CM86-655	do	hourgl	7,0	9,3	75
?Ictidosuchoides BP/1/2294	do	recta	6,7	9,9	68
Tetracynodon AM 3677	do	recta			
Microgomphodon SAM-PK-K10160	ve		10,2	13,2	77
NON-MAMMALIAMORPH CYNODONTIA					
Procynosuchus BP/1/591	do	recta, me side concave	9,0	10,6	85
Procynosuchus NHMUK PV R 37054	do	semi-recta	15,1	14,3	106
*Procynosuchus*RC92	do	recta	13,3	12,0	111
Galesaurus BP/1/2513	do	recta	10,0	11,4	88
Galesaurus SAM-PK-K10465	do	recta to ovoid			*82*
Thrinaxodon BP/1/1737	ve		8,7	11,5	76
Thrinaxodon BP/1/7199	do	recta			
Diademodon NHMUK R-3581	do	semi-recta, me side concave	8,1	11,5	70
Diademodon USNM 23352	do	hourgl			*108*
Cynognathia indet. BP/1/4534	do	recta	2,7	4,7	57
Exaeretodon PVL 2554	do	semi-recta			*98*
Trucidocynodon UFRGS PV-1051T	do	recta, me side concave			*88*
MAMMALIAMORPHA					
Tritylodontidae indet. WCW-06A-34	do	pentagonal	7,0	11,7	60
Bienotheroides IVPP V 7905	do	recta	12,2	19,6	62
Kayentatherium TMM 43690-5.136					
(Hoffmann & Rowe 2018)					
Jeholodens GMV 2139a	do		0,9	3,1	29
Zhangheotherium IVPP V7466	do	irr triangular	1,2	6,4	18
Eomaia CAGS01-IG-1a	do		1,0	4,4	23

Table S3(2): Position and anatomical contacts of the ulnare. **Abbreviations**: **di** distal carpal/distal carpals, **dist** distal, **int** intermedium, **la** lateral, **lce** lateral centrale, **li** little, **lu** lunate, **mc** metacarpal, **me** medial, **pis** pisiform, **ra** radius, **ur** ulnare. * Ulna absent; distal contact of ulna judged from carpal joint facies.

Table S3(2)	**ulnare**	**ulnare**	**ulnare**	**ulnare**	**ulna**
ulnare	**me**	**dist-me**	**dist**	**dist-la**	**dist**
taxon	**c**	**d**	**e**	**f**	**g**
CASEIDAE					
Euromycter MNHN.F.MCL-2	lce, int		di IV	di V	ur, int
(Sigogneau-Russell and Russell 1974)					
Cotylorhynchus OMNH 00655 (Stovall et al. 1966)	lce, int	lce	di IV	di V	ur, int*
"EUPELYCOSAURIA"					
Ophiacodon FMNH UC 458	lce, int		di IV	di V	ur*
Ophiacodon MCZ 1203	lce, int		di IV, di V	mc V?	ur*
Ophiacodon FMNH UC 671	lce, int	di IV	di IV, di V	li space	ur
Edaphosaurus NHMUK R 9204 (cast)	lce, int		di IV	di V	ur*
Sphenacodon CM 76895 (Henrici et al. 2005)	lce, int		di IV	space	ur*
Dimetrodon MCZ 1365 (cast)	lce, int		di IV, di V	di V	
BIARMOSUCHIA					
Biarmosuchidea indet. PIN 1758/320	lce, int		di IV (+di V)	space	ur
Hipposaurus SAM-PK-9081	lce, int		di IV (+di V)	space	ur
DINOCEPHALIA					
Titanophoneus PIN 157/1	lce, int		di IV, di V	li space	ur, int
Estemmenosuchus PIN 1758/23	lce, int		di IV, di V	space	ur, int
ANOMODONTIA					
Suminia PIN 2212/62 (Fröbisch & Reisz 2011)	lce, int		di IV		ur
Galechirus SAM-PK-1068	lce, int		di IV	di V, li space	ur

Galechirus AMNH 5516					
Eosimops BP/1/6674					
Robertia SAM-PK-11885a					
Robertia SAM-PK-11885b	lce, int				ur, pis
Diictodon CGS FL186	lce, int	di IV		space	ur
Diictodon TM4991	lce, int	di IV	di IV	mc V, li space	ur
Diictodon UMZC T 420					
Diictodon GPIT/RE/7193	lce, int	lce	di IV	mc V	ur
Diictodon SAM-PK-K10699	lce, int		di IV	mc V	ur
Diictodon CGS RMS214	lce, int	lce	di IV	mc V	ur
Diictodon CGS T72	int	lce	di IV	li space, ve view	ur
Cistecephalus BP/1/2124	int		di IV	mc V?	ur
Cistecephalus BP/1/2915	int		di IV		
Kannemeyeria NHMUK R 3741	lce, int		di IV (me half of ur)		ur
Stahleckeria MCZ 1688	lce, int		di IV	mc V	ur, int
GORGONOPSIA					
Arctognathus SAM-PK-3329					
Aelurognathus SAM-PK-2342			di IV+V	di V (fused to IV)	ur*
cf. *Cynariops* SAM-PK-K10000			di IV, di V	probably space	ur
Dinogorgon BP/1/2190	lce, int		di IV+di V	di V (fused to IV)	ur
Gorgonopsia indet. BP/1/1210	lce, int		di IV+di V	di IV+V	
THEROCEPHALIA					
Glanosuchus SAM-PK-K7809	lce, int		di IV+di V	mc V?	ur, int
Glanosuchus SAM-PK-12051	lce, int		di IV+di V		ur, int*
Glanosuchus CGS RS424	lce, int		di IV (me half of ur)	mc V	ur, int?*
*Olivierosuchus*BP/1/3973	lce, int		di IV (me half of ur)	big space	ur
Olivierosuchus BP/1/3849			di IV (me half of ur)		
Theriognathus NHMUK R 5694	lce, int		di V		
Ictidosuchoides CGS CM86-655	lce, int		di IV	di V	ur
?Ictidosuchoides BP/1/2294	lce, int		di IV	li space	ur
Tetracynodon AM 3677	lce (int)	di IV		space	ur*
Microgomphodon SAM-PK-K10160	lce, int		di IV+di V		ur
NON-MAMMALIAMORPH CYNODONTIA					
Procynosuchus BP/1/591	lce, int		di IV, di V	li space	ur
Procynosuchus NHMUK PV R 37054	lce, int		di IV	di V, li space	ur*
Procynosuchus RC92	lce, int	di IV		di IV(+V), mc V	ur
Galesaurus BP/1/2513	lce, int		di IV (me half of ur)	space	ur
Galesaurus SAM-PK-K10465	lce, int	di IV		space	ur
Thrinaxodon BP/1/1737			di IV	di V, space?	ur
Thrinaxodon BP/1/7199	lce, int		di IV	di V, space	ur
Diademodon NHMUK R-3581	lce, int		di IV (me half of ur), di V	space	ur
Diademodon USNM 23352	lce, int		di IV (me half of ur)	big space	ur
Cynognathia indet. BP/1/4534	lce, (int)		di IV	space	ur
Exaeretodon PVL 2554	lce, int		di IV (me half of ur)	space	ur
Trucidocynodon UFRGS PV-1051T	lce, int		di IV (me half of ur)	big space	ur, int?*
MAMMALIAMORPHA					
Tritylodontidae indet. WCW-06A-34	lu, ra	di IV	di IV (me half of ur)	space	ur
Bienotheroides IVPP V 7905	lu, ra	di IV	di IV	space	ur
Kayentatherium TMM 43690-5.136 (Hoffmann & Rowe 2018)					
Jeholodens GMV 2139a	lu	di IV		space	ur, pis
Zhangheotherium IVPP V7466	lu, ra		di IV	mc V?	ur
Eomaia CAGS01-IG-1a	lu	di IV		space	ur, pis

Table S4: Shape and position of the pisiform. **Abbreviations**: **dist** distal, **irr** irregular, **me** medial, **pis** pisiform, **pr** proximal, **recta** rectangular, **sh** shaped, **tria** triangular, **ul** ulna, **ur** ulnare, **ve** ventral. * After Henrici et al. (2005).

Table S4	**view**	**pis**	**pis**
pisiform	**of**	**shape, presence**	**position (possibly displaced)**
taxon	**bone**	**a**	**b**
CASEIDAE			
Euromycter rutenus MNHN.F.MCL-2	do	square	la of ur
(Sigogneau-Russell and Russell 1974)			
Cotylorhynchus romeri OMNH 00655 (Stovall et al. 1966)	do	ovoid	la of ul, pr-la of ur
"EUPELYCOSAURIA"			
Ophiacodon retroversus FMNH UC 458		pis not present	
Ophiacodon retroversus MCZ 1203	do	square	la of ul
Ophiacodon mirus FMNH UC 671		pis not present	

*Edaphosaurus boanerges*NHMUK R 9204 (cast)		pis not present	
Sphenacodon ferox CM 76895 (Henrici et al. 2005)	ve	elongate oval*	dist-la of ul, pr-la of ur, partly ve
Dimetrodon milleri MCZ 1365 (cast)	do	square	pr-la of ur, partly ve
BIARMOSUCHIA			
Biarmosuchidea indet. PIN 1758/320	do	ovoid	dist-la of ul, pr-la of ur
Hipposaurus major SAM-PK-9081	do	triangular	la of ul
DINOCEPHALIA			
Titanophoneus potens PIN 157/1		pis not present	
Estemmenosuchus uralensis PIN 1758/23	do	subcircular	dist-la of ul, pr-la of ur
ANOMODONTIA			
Suminia getmanovi PIN 2212/62 (Fröbisch & Reisz 2011)	ve	square to ovoid	la of ul, pr-la of ur, partly ve
Galechirus scholtzi SAM-PK-1068	do	square to ovoid, irr	dist-la of ul, la of ur
Galechirus scholtzi AMNH 5516	do	subcircular	
Eosimops newtoni BP/1/6674		?	
Robertia broomiana SAM-PK-11885a		?	
Robertia broomiana SAM-PK-11885b	ve	ovoid	dist-la of ul, la of ur
Diictodon feliceps CGS FL186		pis not present	
Diictodon feliceps TM4991		pis not present	
Diictodon feliceps UMZC T 420		pis not present	
Diictodon feliceps GPIT/RE/7193		pis not present	
Diictodon feliceps SAM-PK-K10699		pis not present	
Diictodon feliceps CGS RMS214		pis not present	
Diictodon feliceps CGS T72	ve	subcircular	dist-la of ul, pr-la of ur
Cistecephalus microrhinus BP/1/2124		pis not present	
Cistecephalus microrhinus BP/1/2915	ve	ovoid	
Kannemeyeria simocephalus NHMUK R 3741		pis not present	
Stahleckeria potens MCZ 1688		pis not present	
GORGONOPSIA			
Arctognathus curvimola SAM-PK-3329		?	
Aelurognathus tigriceps SAM-PK-2342		?	
cf. *Cynariops robustus* SAM-PK-K10000	ve	ovoid	dist-la of ul, pr-la of ur, partly ve
Dinogorgon rubidgei BP/1/2190		pis not present	
Gorgonopsia indet. BP/1/1210		pis not present	
THEROCEPHALIA			
Glanosuchus macrops SAM-PK-K7809		pis not present	
Glanosuchus macrops SAM-PK-12051		pis not present	
Glanosuchus macrops CGS RS424		?	
Olivierosuchus parringtoni BP/1/3973	ve	subcircular	dist-la of ul, pr-la of ur
Olivierosuchus parringtoni BP/1/3849		triangular?	
Theriognathus microps NHMUK R 5694		?	
Ictidosuchoides longiceps CGS CM86-655		pis not present	
?Ictidosuchoides longiceps BP/1/2294		subcircular	la of ul
Tetracynodon darti AM 3677	do	subcircular	dist-la of ul, pr-la of ur
Microgomphodon oligocynus SAM-PK-K10160		pis not seen	
NON-MAMMALIAMORPH CYNODONTIA			
Procynosuchus delaharpeae BP/1/591	do	subcircular	dist-la of ul, pr/pr-la of ur
Procynosuchus delaharpeae NHMUK PV R 37054	do	ovoid, irr	dist-la of ul, pr/pr-la of ur
Procynosuchus delaharpeae RC92	do	ovoid	dist-la of ul, pr-la of ur
Galesaurus planiceps BP/1/2513	do	bean-sh?	dist-la of ul, pr/pr-la of ur
Galesaurus planiceps SAM-PK-K10465	do	subcircular - square	dist-la of ul, pr-la of ur
Thrinaxodon liorhinus BP/1/1737		pis not present	
Thrinaxodon liorhinus BP/1/7199		subcircular	dist-la of ul, pr-la of ur
Diademodon tetragonus NHMUK R-3581	do	subcircular to tria (?)	pr-la of ur(?), partly ve?
Diademodon tetragonus USNM 23352	do	subcircular to square to sicle-sh	dist-la of ul, pr-la of ur
Cynognathia indet. BP/1/4534		pis not present	
Exaeretodon argentinus PVL 2554		pis not present	
Trucidocynodon riograndensis UFRGS PV-1051T	do	sicle-sh	dist-la of ul, pr-la of ur
MAMMALIAMORPHA			
Tritylodontidae indet. WCW-06A-34		pis not present	
Bienotheroides wanhsienensis IVPP V 7905	do	sicle-sh	dist-la of ul, la?/pr-la? of ur
Kayentatherium wellesi TMM 43690-5.136		pis not present	
(Hoffmann & Rowe 2018)			
Jeholodens jenkinsi GMV 2139a	do	subcircular to ovoid	dist-la of ul, pr-la of ur
Zhangheotherium quinquecuspidens IVPP V7466	do	recta, pr-dist	la of ul, pr/pr-la of ur
Eomaia scansoria CAGS01-IG-1a	do	ovoid	la of ur

Table S5: Shape, position and anatomical contacts of the non-mammaliamorph lateral centrale and the mammaliamorph lunate. **Abbreviations**: **approx** approximately, **di** distal carpal/distal carpals, **dist** distal, **extens** extension, **hourgl** hourglass-shaped, **irr** irregular, **la** lateral, **lce** lateral centrale, **li** little, **lu** lunate, **mce** medial centrale, **me** medial, **pa** partly, **pr** proximal, **recta** rectangular, **rhomb** rhomboid, **rl** radiale, **rel** relation, **tria** triangular, **ur** ulnare. * Proportion judged from photos (in caseids and *Suminia* from figures).

Table S5	**view**	**lce**	**lce length**	**lce**	**lce**	**lce**
lateral centrale and lunate	**of**	**shape**	**in relation to rl***	**dist**	**dist-me**	**dist-la**
taxon	**fossil**	**a**	**b**	**c**	**d**	**e**
CASEIDAE						
Euromycter rutenus MNHN.F.MCL-2	do	square	longer	mce		di IV
(Sigogneau-Russell and Russell 1974)						
Cotylorhynchus romeri OMNH 00655 (Stovall et al. 1966)	do	square	shorter	mce		di IV
"EUPELYCOSAURIA"						
Ophiacodon retroversus FMNH UC 458	do	subcircular	approx same length	di III	mce	di IV
Ophiacodon retroversus MCZ 1203	do	square	approx same length	di III	mce	di IV
Ophiacodon mirus FMNH UC 671	do	recta, dist-pr	approx same length	di III	mce	di IV
*Edaphosaurus boanerges*NHMUK R 9204 (cast)	do	square, irr	longer	di III	di II, mce	di IV
Sphenacodon ferox CM 76895 (Henrici et al. 2005)	do			di III	mce	di IV
Dimetrodon milleri MCZ 1365 (cast)	do	recta, dist-pr, irr		di III	mce	di IV
BIARMOSUCHIA						
Biarmosuchidea indet. PIN 1758/320	do	rhomb, irr	approx same length	di III, di IV pa	mce	
Hipposaurus major SAM-PK-9081	do	rhomb, irr	approx same length	di III	mce	di IV
DINOCEPHALIA						
Titanophoneus potens PIN 157/1	do	rhomb, irr	approx same length	di III, di IV		di IV
Estemmenosuchus uralensis PIN 1758/23	do	recta, irr	approx same length	di III	di II	di IV
ANOMODONTIA						
Suminia getmanovi PIN 2212/62 (Fröbisch & Reisz 2011)	ve	square (la), subcircular (me)	shorter	di III	di II, mce	di IV
Galechirus scholtzi SAM-PK-1068	do	recta, ~dist-pr	shorter	di III	di II, mce	di IV
Galechirus scholtzi AMNH 5516	do	ovoid				
Eosimops newtoni BP/1/6674	ve	square	approx same length	di III	mce	di IV
Robertia broomiana SAM-PK-11885a						
Robertia broomiana SAM-PK-11885b	ve	ovoid		di III		di IV
Diictodon feliceps CGS FL186	do	ovoid to tria	shorter	space	mce	di IV
Diictodon feliceps TM4991	do	ovoid	approx same length	di IV, space	mce	di IV
Diictodon feliceps UMZC T 420	ve	ovoid				
Diictodon feliceps GPIT/RE/7193	do	ovoid	approx same length	di III	mce	di IV
Diictodon feliceps SAM-PK-K10699	do	ovoid	approx same length	di III	mce	di IV
Diictodon feliceps CGS RMS214	ve	ovoid to recta	approx same length		mce	
Diictodon feliceps CGS T72	ve	ovoid	shorter	di III	mce	di IV
Cistecephalus microrhinus BP/1/2124	do	recta, dist-pr	shorter	space		di IV
Cistecephalus microrhinus BP/1/2915	ve	recta, dist-pr, irr	shorter	di III		di III, di IV
Kannemeyeria simocephalus NHMUK R 3741	do	square	shorter	di III	di II, mce?	di IV
Stahleckeria potens MCZ 1688	do	ovoid	approx same length	di II/III, di IV	di I	di IV
GORGONOPSIA						
Arctognathus curvimola SAM-PK-3329	do	recta, slender, irr	shorter	di III, di IV		
Aelurognathus tigriceps SAM-PK-2342	do	rhomb, irr	longer	di III	di II, mce	di IV
cf. *Cynariops robustus* SAM-PK-K10000	ve	ovoid				
Dinogorgon rubidgei BP/1/2190	ve	ovoid	approx same length	di III, di IV	mce	
Gorgonopsia indet. BP/1/1210	do	ovoid	approx same length	di III, di IV	mce	di IV
THEROCEPHALIA						
Glanosuchus macrops SAM-PK-K7809	do	recta, irr, bent	longer	di III, di II	mce	di IV
Glanosuchus macrops SAM-PK-12051	do	rhomb, irr, bent	longer	di III	mce	di IV
Glanosuchus macrops CGS RS424	do	rhomb, irr	longer	di III, (di II)		di IV
Olivierosuchus parringtoni BP/1/3973	ve	ovoid	longer	di III	space	di IV
Olivierosuchus parringtoni BP/1/3849						
Theriognathus microps NHMUK R 5694	do	ovoid to rhomb	shorter	di III, (di II)		di IV+di V
Ictidosuchoides longiceps CGS CM86-655	do	ovoid to rhomb	approx same length	di III		di IV
?Ictidosuchoides longiceps BP/1/2294						
Tetracynodon darti AM 3677	do	ovoid	shorter	di III, di IV	mce	di IV
Microgomphodon oligocynus SAM-PK-K10160	ve	rhomb	approx same length			
NON-MAMMALIAMORPH CYNODONTIA						
Procynosuchus delaharpeae BP/1/591	do	recta to rhomb, irr	approx same length	di III		di IV
Procynosuchus delaharpeae NHMUK PV R 37054	do	recta to rhomb, irr	approx same length	di III	mce	di IV
Procynosuchus delaharpeae RC92	do	recta with extens dist-la	approx same length	di III		di IV
Galesaurus planiceps BP/1/2513	do	recta to rhomb, irr	longer	di III		di IV
Galesaurus planiceps SAM-PK-K10465	do	ovoid, irr	longer	di III	mce	di IV
Thrinaxodon liorhinus BP/1/1737	ve	ovoid, me flat				

Thrinaxodon liorhinus BP/1/7199	do	ovoid, me flat				
Diademodon tetragonus NHMUK R-3581	do	recta to rhomb, extens dist-la	longer	di III	mce	di IV
Diademodon tetragonus USNM 23352	do	recta, irr	longer	di III	mce	di IV
Cynognathia indet. BP/1/4534	do	recta, irr	longer (?)	di III	mce?	di IV
Exaeretodon argentinus PVL 2554	do	recta to rhomb	longer	di III		di IV
Trucidocynodon riograndensis UFRGS PV-1051T	do	recta	longer	di III		di IV
Table S5 continued	**view**	**lu**	**lu length**	**lu**	**lu**	**lu**
lateral centrale and lunate	**of**	**shape**	**in relation to rl***	**dist**	**dist-me**	**dist-la**
	fossil	**a**	**b**	**c**	**d**	**e**
MAMMALIAMORPHA						
Tritylodontidae indet. WCW-06A-34	do	square, massiv	longer	di III	ce	di IV
Bienotheroides wanhsienensis IVPP V 7905	do	square, hourgl	longer	di III	ce	di IV
Kayentatherium wellesi TMM 43690-5.136 (Hoffmann & Rowe 2018)	do	ovoid, la flat	longer	di III(?)	ce	di IV
Jeholodens jenkinsi GMV 2139a	do	ovoid	longer	di III	ce	di IV
Zhangheotherium quinquecuspidens IVPP V7466	do	subcircular	longer	di III	ce	di IV
Eomaia scansoria CAGS01-IG-1a	do	tria	longer			

Table S6: Shape, position and anatomical contacts of the non-mammaliamorph medial centrale and the mammaliamorph centrale. **Abbreviations**: **ce** centrale, **di** distal carpal/distal carpals, **dist** distal, **f** fused, **irr** irregular, **la** lateral, **lce** lateral centrale, **li** little, **lu** lunate, **mce** medial centrale, **p/s** prepollex/sesamoid, **pr** proximal, **recta** rectangular, **rhomb** rhomboid, **rl** radiale, **sh** shaped, **tria** triangular.

Table S6	**view**	**mce**	**mce**	**mce**	**mce**	**mce**	**state of**
medial centrale and single centrale	**of**	**shape**	**pr**	**pr-la**	**la**	**dist-la, dist, dist-me**	**mce**
taxon	**fossil**	**a**	**b**	**c**	**d**	**e**	**f**
CASEIDAE							
Euromycter rutenus MNHN.F.MCL-2 (Sigogneau-Russell and Russell 1974)	do	recta, transverse	rl, lce		di IV	di III, di II, di I	seperate
Cotylorhynchus romeri OMNH 00655 (Stovall et al. 1966)	do	lense-sh	rl, lce		di IV	di III, di II	seperate
"EUPELYCOSAURIA"							
Ophiacodon retroversus FMNH UC 458	do	ovoid, transverse	rl	lce		(di III), di II, di I	seperate
Ophiacodon retroversus MCZ 1203	do	pentagonal, irr	rl	lce		(di III), di II, di I	seperate
Ophiacodon mirus FMNH UC 671	do	ovoid, transverse	rl	lce		(di III), di II, di I	seperate
*Edaphosaurus boanerges*NHMUK R 9204 (cast)	do	recta, transverse	rl	rl, lce		di II, di I	seperate
Sphenacodon ferox CM 76895 (Henrici et al. 2005)	do	ovoid, irr	rl	rl, lce	lce	di III, di II,di I	seperate
Dimetrodon milleri MCZ 1365 (cast)	do	recta, transverse	rl	rl, lce		di III, di II,di I	seperate
BIARMOSUCHIA							
Biarmosuchidea indet. PIN 1758/320	do	rhomb	rl	rl, lce		di III, di II, di I, p/s	seperate
Hipposaurus major SAM-PK-9081	do	rhomb	rl	lce	lce	(di III), di II, di I	seperate
DINOCEPHALIA							
Titanophoneus potens PIN 157/1	do	rhomb		rl	lce	di II, di I	seperate
Estemmenosuchus uralensis PIN 1758/23	do	ovoid		rl	lce	di II, di I	seperate
ANOMODONTIA							
Suminia getmanovi PIN 2212/62 (Fröbisch & Reisz 2011)	ve	lense-sh, small	rl		lce	di II, di I	seperate
Galechirus scholtzi SAM-PK-1068	do	recta, ~transverse	rl	lce	lce	di II, di I	seperate
Galechirus scholtzi AMNH 5516							
Eosimops newtoni BP/1/6674	ve	ovoid	rl	lce		di III, space, di I	seperate
Robertia broomiana SAM-PK-11885a	do	ovoid, irr	rl			di III, di II, di I	seperate
Robertia broomiana SAM-PK-11885b	ve	ovoid	rl				seperate
Diictodon feliceps CGS FL186	do	ovoid, pr flat	rl	lce		space, di I	seperate
Diictodon feliceps TM4991	do	ovoid	rl	rl, lce		space, di I	seperate
Diictodon feliceps UMZC T 420	ve	ovoid					seperate
Diictodon feliceps GPIT/RE/7193	do	ovoid	rl	lce		di II, di I	seperate
Diictodon feliceps SAM-PK-K10699	do	ovoid	rl	lce		di II, di I	seperate
Diictodon feliceps CGS RMS214	ve	ovoid, pr flat	rl	lce		di III, space, di I	seperate
Diictodon feliceps CGS T72	ve	ovoid	rl	lce		di III, space, di I	seperate
Cistecephalus microrhinus BP/1/2124	do	ovoid, pr flat	rl				seperate
Cistecephalus microrhinus BP/1/2915	ve	ovoid, irr	rl			di II, mcII, di I?	seperate
Kannemeyeria simocephalus NHMUK R 3741							
Stahleckeria potens MCZ 1688							absent
GORGONOPSIA							
Arctognathus curvimola SAM-PK-3329	do	recta, slender		rl (fused)		di III, di II, di I	mce f to rl
Aelurognathus tigriceps SAM-PK-2342	do	recta	rl	lce		di II, di I	seperate
cf. *Cynariops robustus* SAM-PK-K10000	ve	ovoid to recta, pr flat	rl				seperate
Dinogorgon rubidgei BP/1/2190	ve	recta, flat	rl	lce		(di III), di II, di I	seperate

Gorgonopsia indet. BP/1/1210	do	ovoid to recta, pr flat	rl	rl, lce		di II, di I	seperate
THEROCEPHALIA							
Glanosuchus macrops SAM-PK-K7809	do	ovoid, dist flat	rl	lce		di II, di I	seperate
Glanosuchus macrops SAM-PK-12051	do	square	rl	rl, lce	lce	(di III), di II, di I	seperate
Glanosuchus macrops CGS RS424	do	ovoid, dist flat	rl	rl	lce	di II, di I	seperate
Olivierosuchus parringtoni BP/1/3973							
Olivierosuchus parringtoni BP/1/3849	do	ovoid, dist flat					seperate
Theriognathus microps NHMUK R 5694	do	both square	rl	rl	lce	di II, di I (2 mce)	duplicated (?)
Ictidosuchoides longiceps CGS CM86-655	do	square	rl	rl	lce	(di III), di II, di I	seperate
?Ictidosuchoides longiceps BP/1/2294	do		rl	rl			seperate
Tetracynodon darti AM 3677	do	ovoid	rl	rl, lce		di III, di II, di I	seperate
Microgomphodon oligocynus SAM-PK-K10160							
NON-MAMMALIAMORPH CYNODONTIA							
Procynosuchus delaharpeae BP/1/591	do	ovoid, irr	rl		lce	di II, di I	seperate
Procynosuchus delaharpeae NHMUK PV R 37054	do	rectangular, irr	rl	lce	lce, space	di II, di I	seperate
Procynosuchus delaharpeae RC92	do	ovoid	rl		di III	di II, di I	seperate
Galesaurus planiceps BP/1/2513	do	ovoid, pr flat	rl		lce	di III, di II, di I	seperate
Galesaurus planiceps SAM-PK-K10465	do	ovoid, pr flat	rl	lce	space	(di III), di II, di I	seperate
Thrinaxodon liorhinus BP/1/1737	ve	ovoid, pr flat?	rl? (fused?)				mce f to rl?
Thrinaxodon liorhinus BP/1/7199	do	ovoid, pr flat	rl			di III, di II, di I	seperate
Diademodon tetragonus NHMUK R-3581	do	ovoid, pr flat	rl	lce	space	(di III), di II, di I	seperate
Diademodon tetragonus USNM 23352	do	recta, flat	rl	lce		(di III), di II, di I	seperate
Cynognathia indet. BP/1/4534	do	ovoid, pr flat?	rl? (fused?)	lce?	space?		mce f to rl?
Exaeretodon argentinus PVL 2554	do	ovoid, pr flat	rl		di II	di II, di I	seperate
Trucidocynodon riograndensis UFRGS PV-1051T	do	tria, pr flat, dist round	rl		lce	di III?, di II, di I?	seperate
Table S6 continued	**view**	**single ce**	**single ce**	**single ce**	**single ce**	**single ce**	**state of**
medial centrale and single centrale	**of**	**shape**	**pr**	**pr-la**	**la**	**dist-la, dist, dist-me**	**single ce**
	fossil	**a**	**b**	**c**	**d**	**e**	**f**
MAMMALIAMORPHA							
Tritylodontidae indet. WCW-06A-34	do	ovoid, dist flat	rl	lu		(di III), di II, di I	seperate
Bienotheroides wanhsienensis IVPP V 7905	do	ovoid, dist flat	rl	lu	space	(di III), di II, di I	ce f to rl
Kayentatherium wellesi TMM 43690-5.136	do	ovoid	rl	lu	space	di III/II, di I	seperate
(Hoffmann & Rowe 2018)							
Jeholodens jenkinsi GMV 2139a	do	pentagonal	rl	lu	li space	di III, di II, di I	seperate
Zhangheotherium quinquecuspidens IVPP V7466	do	irr pentagonal	rl	lu	lu	di III, di II, di I	seperate
Eomaia scansoria CAGS01-IG-1a							

Table S7: Shape, position and anatomical contacts of distal carpal I. **Abbreviations**: **di** distal carpal/distal carpals, **dist** distal, **f** fused, **la** lateral, **lce** lateral centrale, **mc** metacarpal, **mce** medial centrale, **me** medial, **p/s** prepollex/sesamoid, **pr** proximal, **proc** process, **recta** rectangular, **rl** radiale, **sh** shaped, **sp** space.

Table S7	**view**	**di I**	**di I**	**di I**	**di I**	**space**
distal carpal I	**of**	**shape**	**position**	**pr**	**pr-la**	**pr di I**
taxon	**fossil**	**a**	**b**	**c**	**d**	**e**
CASEIDAE						
Euromycter MNHN.F.MCL-2	do	recta transverse	in row of di	mce		littel sp: dist-me of rl
(Sigogneau-Russell and Russell 1974)						
Cotylorhynchus OMNH 00655 (Stovall et al. 1966)	do	wedge-sh	in row of di	rl		little sp: rl-di I
"EUPELYCOSAURIA"						
Ophiacodon FMNH UC 458	do	ovoid	in row of di		mce	sp: rl-di I
Ophiacodon MCZ 1203	do	ovoid	in row of di		mce?	
Ophiacodon FMNH UC 671	do	sub-ovoid	in row of di		mce	sp: rl-di I
Edaphosaurus NHMUK R 9204 (cast)	do	recta transverse	in row of di	mce		no sp: mce pr di I
Sphenacodon CM 76895 (Henrici et al. 2005)	do	kinked wedge	in row of di		mce	little sp: mce-di I
Dimetrodon MCZ 1365 (cast)	do	recta transverse	in row of di		mce	sp: me part di I
BIARMOSUCHIA						
Biarmosuchidea indet. PIN 1758/320	do	recta transverse		p/s	mce	no sp: p/s pr di I
Hipposaurus SAM-PK-9081	do	square	intermediate		mce	sp: rl-mce-di I
DINOCEPHALIA						
Titanophoneus PIN 157/1	do	square	intermediate		mce	sp: mce-di I
Estemmenosuchus PIN 1758/23	do	recta transverse	intermediate		mce	sp: mce-di I
ANOMODONTIA						
Suminia PIN 2212/62 (Fröbisch & Reisz 2011)	ve	recta pr-dist	intermediate		mce	sp: rl-di I?
Galechirus SAM-PK-1068	do	recta transverse	in row of di		mce	sp: mce-di I
Galechirus AMNH 5516	do		in row of di			
Eosimops BP/1/6674	ve	subcircular to square	intermediate		mce	sp: rl-di I
Robertia SAM-PK-11885a	do	square to subcircular	in row of mc		mce	sp: rl-di I

Robertia SAM-PK-11885b						
Diictodon CGS FL186	do	square	in row of mc		mce	sp: rl-di I
Diictodon TM4991	do	recta pr-dist	in row of mc		mce	sp: rl-di I
Diictodon UMZC T 420	ve		in row of mc			
Diictodon GPIT/RE/7193	do	ovoid dist-pr	in row of mc		mce	sp: ra!-di I
Diictodon SAM-PK-K10699	do	square	in row of mc		mce	sp: rl-di I
Diictodon CGS RMS214	ve	square to subcircular	in row of mc		mce	sp: rl-di I
Diictodon CGS T72	ve		in row of mc		mce	sp: rl-di I
Cistecephalus BP/1/2124	do					no sp: rl contacts di I
Cistecephalus BP/1/2915	ve				mce?	
Kannemeyeria NHMUK R 3741	do	ovoid?	intermediate?			
Stahleckeria MCZ 1688	do	ovoid	intermediate	rl	lce	no sp: rl contacts di I
GORGONOPSIA						
Arctognathus SAM-PK-3329	do		intermediate		mce contact short	little sp: rl-di I
Aelurognathus SAM-PK-2342	do	square	intermdediate		mce contact short	sp: rl-di I
cf. *Cynariops* SAM-PK-K10000	ve					sp: rl-di I
Dinogorgon BP/1/2190						
Gorgonopsia indet. BP/1/1210	do	trapezoidal	intermediate		mce contact very short	sp: rl-di I
THEROCEPHALIA						
Glanosuchus SAM-PK-K7809	do			mce		little sp: rl- di I
Glanosuchus SAM-PK-12051	do					little sp: pr-me di I
Glanosuchus CGS RS424	do	square	intermediate		mce	little sp: pr-me di I
*Olivierosuchus*BP/1/3973	ve		intermediate		mce not present	big sp
Olivierosuchus BP/1/3849	do	recta to square	intermediate			
Theriognathus NHMUK R 5694	do	recta pr-dist	intermediate		me mce contact short	sp: rl-di I
Ictidosuchoides CGS CM86-655	do	square	intermediate		mce contact very short	sp: di I pr free
?Ictidosuchoides BP/1/2294	do					
Tetracynodon AM 3677	do	recta pr-dist	intermediate		mce contact very short	sp: di I pr free
Microgomphodon SAM-PK-K10160	ve	recta pr-dist	in row of mc		mce not present	big sp
NON-MAMMALIAMORPH CYNODONTIA						
Procynosuchus BP/1/591	do		intermediate		mce	sp: mce-di I
Procynosuchus NHMUK PV R 37054	do	square	intermediate		mce	sp: rl-di I
*Procynosuchus*RC92	do	square	in row of mc		mce	sp: rl-di I
Galesaurus BP/1/2513	do	square, pr rounded	intermediate		mce	little sp: rl-di I
Galesaurus SAM-PK-K10465	do	square, me rounded	intermediate		mce	little sp: rl-di I
Thrinaxodon BP/1/1737	ve		intermediate			
Thrinaxodon BP/1/7199	do	recta, pr-di	intermediate		mce	little sp
Diademodon NHMUK R-3581	do	square	intermediate		mce	sp
Diademodon USNM 23352	do	square	intermediate		mce	little sp
Cynognathia indet. BP/1/4534						
Exaeretodon PVL 2554	do	square	in row of mc		mce	sp: rl-di I
Trucidocynodon UFRGS PV-1051T	do					
MAMMALIAMORPHA						
Tritylodontidae indet. WCW-06A-34	do	square to subcircular	intermediate	rl (proc)	ce	no sp: rl meets di I
Bienotheroides IVPP V 7905	do	square	intermediate	rl (proc), ce		no sp: rl meets di I
Kayentatherium TMM 43690-5.136	do	subcircular	intermediate		ce	sp: rl-di I
(Hoffmann & Rowe 2018)						
Jeholodens GMV 2139a	do		in row of di	rl?	ce	no sp
Zhangheotherium IVPP V7466	do	square	in row of di	nodule (p/s?)	ce	no sp: rl-nodule-di I
Eomaia CAGS01-IG-1a	do	recta, pr-dist	in row of di			no sp

Table S8: Shape, position and relative size of distal carpal II. **Abbreviations**: **approx** approximately**, cmc j** carpometacarpal joint, **di** distal carpal/distal carpals, **dist** distal, **pr** proximal, **quadra** quadrangular, **recta** rectangular, **sh** shaped, **tria** triangular. * Proportions of distal carpal length judged from photos (in caseids and *Suminia* from figures).

Table S8	**view**	**di shortest**	**di II shape**	**di II**	**position of**
distal carpal II	**of**	**of di I-IV***	**and presence**	**position**	**cmc j II**
taxon	**fossil**	**a**	**b**	**c**	**d**
CASEIDAE					
Euromycter rutenus MNHN.F.MCL-2	do	di I	quadra to ovoid	ray II	in line with cmc j III-V
(Sigogneau-Russell and Russell 1974)					
Cotylorhynchus romeri OMNH 00655 (Stovall et al. 1966)	do	di I, II (approx equal)	quadra to ovoid	ray II	in line with cmc j III-V
"EUPELYCOSAURIA"					
Ophiacodon retroversus FMNH UC 458	do	di I	ovoid	ray II	in line with cmc j III-V
Ophiacodon retroversus MCZ 1203	do		quadra to ovoid		
Ophiacodon mirus FMNH UC 671	do	di I, II (approx equal)	quadra to ovoid	ray II	in line with cmc j III-V
*Edaphosaurus boanerges*NHMUK R 9204 (cast)	do	di II, III (approx equal)	ovoid	ray II	pr to cmc j III-V
Sphenacodon ferox CM 76895 (Henrici et al. 2005)	do	di I			in line with cmc j III-V

Dimetrodon milleri MCZ 1365 (cast)	do	di I	ovoid to wedge-sh	ray II	in line with cmc j III-V
BIARMOSUCHIA					
Biarmosuchidea indet. PIN 1758/320	do	di II	ovoid	ray II	in line with cmc j III-V
Hipposaurus major SAM-PK-9081	do	di II	ovoid to tria	ray II	in line with cmc j III-V
DINOCEPHALIA					
Titanophoneus potens PIN 157/1	do	di II	ovoid to tria	ray II	in line with cmc j III-V
Estemmenosuchus uralensis PIN 1758/23	do	di II, I (approx equal)	trapezoidal	ray II	
ANOMODONTIA					
Suminia getmanovi PIN 2212/62 (Fröbisch & Reisz 2011)	ve	di II, III (approx equal)	ovoid	ray II	in line with cmc j III-V
Galechirus scholtzi SAM-PK-1068	do	di II, III (approx equal)	subcircular	ray II	pr to cmc j III-V
Galechirus scholtzi AMNH 5516					
Eosimops newtoni BP/1/6674					
Robertia broomiana SAM-PK-11885a	do	di II	subcircular	ray II	in line with cmc j III-V
Robertia broomiana SAM-PK-11885b					
Diictodon feliceps CGS FL186	do		not present		
Diictodon feliceps TM4991	do		not present		
Diictodon feliceps UMZC T 420	ve		not present		
Diictodon feliceps GPIT/RE/7193	do	di II	very small		in line with cmc j III-V
Diictodon feliceps SAM-PK-K10699	do		not present		
Diictodon feliceps CGS RMS214	ve	di II	very small		in line with cmc j III-V
Diictodon feliceps CGS T72	ve		not present		
Cistecephalus microrhinus BP/1/2124	do		ovoid	ray II	dist to cmc j III-V
Cistecephalus microrhinus BP/1/2915	ve	di II	ovoid	ray II	in line with cmc j III-V
Kannemeyeria simocephalus NHMUK R 3741	do		ovoid?		
Stahleckeria potens MCZ 1688	do	di II (III?)	inverted triangle	ray II, partly III	in line with cmc j III-V
GORGONOPSIA					
Arctognathus curvimola SAM-PK-3329	do	di II	recta to ovoid	ray II	in line with cmc j III-V
Aelurognathus tigriceps SAM-PK-2342	do	di II	recta to ovoid	ray II	pr to cmc j III-V
cf. *Cynariops robustus* SAM-PK-K10000	ve		inverted trapezoidal	ray II	pr to cmc j III-V
Dinogorgon rubidgei BP/1/2190	ve	di II	ovoid	ray II	pr to cmc j III-V
Gorgonopsia indet. BP/1/1210	do	di II	pentagonal	ray II	pr to cmc j III-V
THEROCEPHALIA					
Glanosuchus macrops SAM-PK-K7809	do	di II, I (approx equal)	square	ray II	in line with cmc j III-V
Glanosuchus macrops SAM-PK-12051	do	di II			
Glanosuchus macrops CGS RS424	do	di II	ovoid	ray II	in line with cmc j III-V
Olivierosuchus parringtoni BP/1/3973	ve	di III	square to ovoid		
Olivierosuchus parringtoni BP/1/3849	do		not present		
Theriognathus microps NHMUK R 5694	do	di II, IV (approx equal)	pentagonal	ray II	in line with cmc j III-V
Ictidosuchoides longiceps CGS CM86-655	do	di II, III (approx equal)	square	ray II	pr to cmc j III-V
?Ictidosuchoides longiceps BP/1/2294	do				
Tetracynodon darti AM 3677	do	di III	square	ray II	pr to cmc j III-V
Microgomphodon oligocynus SAM-PK-K10160	ve	di II, III (approx equal)			pr to cmc j III-V
NON-MAMMALIAMORPH CYNODONTIA					
Procynosuchus delaharpeae BP/1/591	do	di II	ovoid	ray II	pr to cmc j III-V
Procynosuchus delaharpeae NHMUK PV R 37054	do	di II	ovoid	ray II	in line with cmc j III-V
Procynosuchus delaharpeae RC92	do	di II	flat	ray II	in line with cmc j III-V
Galesaurus planiceps BP/1/2513	do	di II	subcircular	ray II	pr to cmc j III-V
Galesaurus planiceps SAM-PK-K10465	do	di II	subcircular	ray II	in line with cmc j III-V
Thrinaxodon liorhinus BP/1/1737	ve	di II	ovoid	ray II	in line with cmc j III-V
Thrinaxodon liorhinus BP/1/7199	do	di II	ovoid	ray II	in line with cmc j III-V
Diademodon tetragonus NHMUK R-3581	do	di II	ovoid	ray II	pr to cmc j III-V
Diademodon tetragonus USNM 23352	do	di II	subcircular	ray II	in line with cmc j III-V
Cynognathia indet. BP/1/4534	do			ray II	in line with cmc j III-V
Exaeretodon argentinus PVL 2554	do	di III	wedge-shaped	ray II	in line with cmc j III-V
Trucidocynodon riograndensis UFRGS PV-1051T	do	di II	subcircular to tria	ray II	pr to cmc j III-V
MAMMALIAMORPHA					
Tritylodontidae indet. WCW-06A-34	do	di II	recta to ovoid	ray II	in line with cmc j III-V
Bienotheroides wanhsienensis IVPP V 7905	do	di II	ovoid	ray II	in line with cmc j III-V
Kayentatherium wellesi TMM 43690-5.136 (Hoffmann & Rowe 2018)	do		absent or fused?		
Jeholodens jenkinsi GMV 2139a	do	di II(?)	small ovoid?	ray II	pr to cmc j III-V
Zhangheotherium quinquecuspidens IVPP V7466	do	di II	flat ovoid	ray II	pr to cmc j III-V
Eomaia scansoria CAGS01-IG-1a	do	di II	ovoid	ray II	pr to cmc j III-V

Table S9: Shape and position of distal carpal III. **Abbreviations**: **di** distale/distal carpals, **dist** distal, **irr** irregular, **me** medial, **pr** proximal, **quadra** quadrangular, **recta** rectangular, **sh** shaped, **tria** triangular.

Table S9 distal carpal III taxon	view of fossil	di III shape and presence a	di III position b
CASEIDAE			
Euromycter rutenus MNHN.F.MCL-2	do	wedge-sh	ray III
(Sigogneau-Russell and Russell 1974)			
Cotylorhynchus romeri OMNH 00655 (Stovall et al. 1966)	do	wedge-sh to ovoid	ray III
"EUPELYCOSAURIA"			ray III
Ophiacodon retroversus FMNH UC 458	do	ovoid	ray III
Ophiacodon retroversus MCZ 1203	do	ovoid	ray III
Ophiacodon mirus FMNH UC 671	do	square	ray III
*Edaphosaurus boanerges*NHMUK R 9204 (cast)	do	square	ray III
Sphenacodon ferox CM 76895 (Henrici et al. 2005)			
Dimetrodon milleri MCZ 1365 (cast)	do	ovoid	ray III
BIARMOSUCHIA			
Biarmosuchidea indet. PIN 1758/320	do	ovoid, me concave	ray III
Hipposaurus major SAM-PK-9081	do	ovoid	ray III
DINOCEPHALIA			
Titanophoneus potens PIN 157/1	do	recta pr-dist	ray III
Estemmenosuchus uralensis PIN 1758/23	do	square	ray III
ANOMODONTIA			
Suminia getmanovi PIN 2212/62 (Fröbisch & Reisz 2011)	ve	wedge-sh	ray III
Galechirus scholtzi SAM-PK-1068	do	bean-sh	ray III
Galechirus scholtzi AMNH 5516			
Eosimops newtoni BP/1/6674	ve	ovoid	ray III
Robertia broomiana SAM-PK-11885a	do	ovoid	ray III
Robertia broomiana SAM-PK-11885b			
Diictodon feliceps CGS FL186	do	not present	
Diictodon feliceps TM4991	do	not present	
Diictodon feliceps UMZC T 420	ve	not present	
Diictodon feliceps GPIT/RE/7193	do	ovoid	ray III me
Diictodon feliceps SAM-PK-K10699	do	ovoid	ray III me
Diictodon feliceps CGS RMS214	ve	ovoid	ray III me
Diictodon feliceps CGS T72	ve	ovoid	ray III me
Cistecephalus microrhinus BP/1/2124	do	ovoid	ray III
Cistecephalus microrhinus BP/1/2915	ve	pentagonal	ray III
Kannemeyeria simocephalus NHMUK R 3741	do	pentagonal	
Stahleckeria potens MCZ 1688	do	see di II, Table S10b	
GORGONOPSIA			
Arctognathus curvimola SAM-PK-3329	do	ovoid	ray III
Aelurognathus tigriceps SAM-PK-2342	do	pentagonal	ray III
cf. *Cynariops robustus* SAM-PK-K10000	ve	recta	ray III
Dinogorgon rubidgei BP/1/2190	ve	ovoid	ray III
Gorgonopsia indet. BP/1/1210	do	ovoid to pentagonal	ray III
THEROCEPHALIA			
Glanosuchus macrops SAM-PK-K7809	do	recta pr-dist	ray III
Glanosuchus macrops SAM-PK-12051	do		ray III
Glanosuchus macrops CGS RS424	do	ovoid	ray III
Olivierosuchus parringtoni BP/1/3973	ve	ovoid	ray III
Olivierosuchus parringtoni BP/1/3849	do	ovoid- inverted triangle	ray III
Theriognathus microps NHMUK R 5694	do	inverted triangle	ray III
Ictidosuchoides longiceps CGS CM86-655	do	subcircular	ray III
?Ictidosuchoides longiceps BP/1/2294			
Tetracynodon darti AM 3677	do	ovoid	ray III
Microgomphodon oligocynus SAM-PK-K10160	ve	ovoid	ray III
NON-MAMMALIAMORPH CYNODONTIA			
Procynosuchus delaharpeae BP/1/591	do	quadra	ray III
Procynosuchus delaharpeae NHMUK PV R 37054	do	recta	ray III
Procynosuchus delaharpeae RC92	do	ovoid	ray III
Galesaurus planiceps BP/1/2513	do	ovoid	ray III
Galesaurus planiceps SAM-PK-K10465	do	ovoid	ray III
Thrinaxodon liorhinus BP/1/1737	ve	ovoid	ray III
Thrinaxodon liorhinus BP/1/7199	do	bean-sh	ray III
Diademodon tetragonus NHMUK R-3581	do	ovoid	ray III
Diademodon tetragonus USNM 23352	do	irr ovoid	ray III
Cynognathia indet. BP/1/4534	do	recta? pr-dist	ray III
Exaeretodon argentinus PVL 2554	do	ovoid?	ray III

Trucidocynodon riograndensis UFRGS PV-1051T	do	ovoid	ray III
MAMMALIAMORPHA			
Tritylodontidae indet. WCW-06A-34	do	ovoid	ray III
Bienotheroides wanhsienensis IVPP V 7905	do	tria	ray III
Kayentatherium wellesi TMM 43690-5.136	do	bean-sh (fused to di II?)	
(Hoffmann & Rowe 2018)			
Jeholodens jenkinsi GMV 2139a	do	elongated ellipsoidal	ray III
Zhangheotherium quinquecuspidens IVPP V7466	do	ovoid	ray III
Eomaia scansoria CAGS01-IG-1a	do	ovoid	ray III

Table S10(1): Presence, shape and relative size of distal carpal IV and V. **Abbreviations**: **abs** absent, **approx** approximately, **di** distal carpal/distal carpals, **dist** distal, **f** fused, **irr** irregular, **nu** number, **pr** proximal, **pres** preserved, **quadra** quadrangular, **recta** rectangular, **sh** shaped, **tria** triangular. * Proportions of distal carpal length judged from photos (in caseids and *Suminia* from figures). ** Fused after Chudinov (1983), see reference list in the text.

Table S10(1)	**view**	**di**	**di IV**	**di V**	**nu**	**state of di V**
distal carpals IV and V	**of**	**longest***	**shape**	**shape**	**of di**	
taxon	**fossil**	**a**	**b**	**c**	**d**	**e**
CASEIDAE						
Euromycter MNHN.F.MCL-2	do	di IV	pentagonal	flat tria	5	seperate
(Sigogneau-Russell and Russell 1974)						
Cotylorhynchus OMNH 00655 (Stovall et al. 1966)	do	di IV	pentagonal	flat tria	5	seperate
"EUPELYCOSAURIA"						
Ophiacodon FMNH UC 458	do	di IV	pentagonal to ovoid		5	seperate
Ophiacodon MCZ 1203	do	di IV	ovoid	small bone, shape?	5	seperate
Ophiacodon FMNH UC 671	do	di IV	pentagonal to ovoid	ovoid	5	seperate
Edaphosaurus NHMUK R 9204 (cast)	do	di IV	pentagonal to ovoid	ovoid	5	seperate
Sphenacodon CM 76895 (Henrici et al. 2005)						
Dimetrodon MCZ 1365 (cast)	do	di IV	pentagonal	tria	5	seperate
BIARMOSUCHIA						
Biarmosuchidea indet. PIN 1758/320	do	di IV	square to subcircular	ovoid	4	f to IV**, (fusion line)
Hipposaurus SAM-PK-9081	do	di IV, I (approx equal)	recta transverse	square to ovoid	4	f to IV, fusion line
DINOCEPHALIA						
Titanophoneus PIN 157/1	do	di IV	pentagonal	ovoid	5	seperate
Estemmenosuchus PIN 1758/23	do	di IV	square	ovoid	5	seperate
ANOMODONTIA						
Suminia PIN 2212/62 (Fröbisch & Reisz 2011)	ve	di I	inverse trapezoidal to recta			
Galechirus SAM-PK-1068	do	di IV	pentagonal	ovoid	5	seperate
Galechirus AMNH 5516	do	di IV			5	seperate
Eosimops BP/1/6674	ve	di IV	subcircular to square		4	
Robertia SAM-PK-11885a	do		inverse trapezoidal		4	
Robertia SAM-PK-11885b	ve		inverse trapezoidal		4	
Diictodon CGS FL186	do	di I	tria		2	
Diictodon TM4991	do	di I	pentagonal		2	
Diictodon UMZC T 420	ve	di I	subcircular to square		2	
Diictodon GPIT/RE/7193	do	di I	square		4	
Diictodon SAM-PK-K10699	do	di I	?		3	
Diictodon CGS RMS214	ve	di I	square		3 or 4	
Diictodon CGS T72	ve	di I	pentagonal			
Cistecephalus BP/1/2124	do		inverse trapezoidal			
Cistecephalus BP/1/2915	ve		inverse trapezoidal			
Kannemeyeria NHMUK R 3741	do		inverse trapezoidal			
Stahleckeria MCZ 1688	do	di I	inverse trapezoidal (?)		3	
GORGONOPSIA						
Arctognathus SAM-PK-3329	do	di I, IV (approx equal)	pentagonal	inverse trapezoid	4	f to IV, fusion line
Aelurognathus SAM-PK-2342	do	di I, IV (approx equal)	irr ovoid		4	f to IV
cf. *Cynariops* SAM-PK-K10000	ve	di I, IV (approx equal)	pentagonal	quadra	5	seperate
Dinogorgon BP/1/2190	ve		pentagonal	quadra	4	f to IV, fusion line
Gorgonopsia indet. BP/1/1210	do	di I, IV (approx equal)	irr recta	inverse triangular	4	f to IV, fusion line
THEROCEPHALIA						
Glanosuchus SAM-PK-K7809	do	di IV	square to ovoid		4	f to IV
Glanosuchus SAM-PK-12051						
Glanosuchus CGS RS424	do	di IV	pentagonal		4	probably fused
*Olivierosuchus*BP/1/3973	ve	di I	ovoid		4	
Olivierosuchus BP/1/3849	do	di I	irr recta			
Theriognathus NHMUK R 5694	do	di I	irr recta	tria	4	f to IV, fusion line
Ictidosuchoides CGS CM86-655	do	di I	ovoid	tria	5	seperate

?Ictidosuchoides BP/1/2294	do		irr ovoid		4	f to IV
Tetracynodon AM 3677	do	di I	ovoid		4	
Microgomphodon SAM-PK-K10160	ve	di I	ovoid		4	f to IV, fusion line
NON-MAMMALIAMORPH CYNODONTIA						
Procynosuchus BP/1/591	do		recta pr-di	tria	5	seperate
Procynosuchus NHMUK PV R 37054	do	di IV	ovoid	ovoid	5	seperate
*Procynosuchus*RC92	do	di I	square with indentation		4	f to IV
Galesaurus BP/1/2513	do	di I	ovoid		4	
Galesaurus SAM-PK-K10465	do	di I	ovoid		4	
Thrinaxodon BP/1/1737	ve	di I	recta to ovoid	subcircular to tria	5	seperate
Thrinaxodon BP/1/7199	do	di I	ovoid	ovoid to tria	5	seperate
Diademodon NHMUK R-3581	do	di I	square		5	seperate
Diademodon USNM 23352	do	di I	ovoid	very small, ovoid (?)	5(?)	seperate(?)
Cynognathia indet. BP/1/4534	do		ovoid		4	
Exaeretodon PVL 2554	do	di I	trapezoidal		4	
Trucidocynodon UFRGS PV-1051T	do		ovoid		4	
MAMMALIAMORPHA						
Tritylodontidae indet. WCW-06A-34	do	di I	inverted drop-sh		4	
Bienotheroides IVPP V 7905	do	di I	irr tria		4	
Kayentatherium TMM 43690-5.136	do	di I, IV (approx equal)	irr ovoid		3	
(Hoffmann & Rowe 2018)						
Jeholodens GMV 2139a	do	di I?	irr pentagonal		4	
Zhangheotherium IVPP V7466	do	di I, IV (approx equal)	pentagonal to ovoid		4	
Eomaia CAGS01-IG-1a	do		irr tria		4	

Table S10(2): Position of distal carpal IV and V. **Abbreviations**: **di** distal carpal/distal carpals, **dist** distal, **la** lateral, **mc** metacarpal, **me** medial, **pr** proximal, **ur** ulnare.

Table S10(2)	**di IV**	**di V**	**mc V connected**
distal carpals IV and V	**position**	**position**	**pr to**
taxon	**f**	**g**	**h**
CASEIDAE			
Euromycter MNHN.F.MCL-2	ray IV	ray V	di V
(Sigogneau-Russell and Russell 1974)			
Cotylorhynchus OMNH 00655 (Stovall et al. 1966)	ray IV	ray V	di V
"EUPELYCOSAURIA"			
Ophiacodon FMNH UC 458	ray IV	ray V	
Ophiacodon MCZ 1203	ray IV	ray V (me part)	di V, pr-la partly ur?
Ophiacodon FMNH UC 671	ray IV	ray V	di V
Edaphosaurus NHMUK R 9204 (cast)	ray IV	ray V	di V
Sphenacodon CM 76895 (Henrici et al. 2005)			
Dimetrodon MCZ 1365 (cast)	ray IV	ray V	di V
BIARMOSUCHIA			
Biarmosuchidea indet. PIN 1758/320	ray IV, ray V (me part)	ray V (la part)	di IV+V, space
Hipposaurus SAM-PK-9081	ray IV, ray V (me part)	ray V (la part)	di IV+V, space
DINOCEPHALIA			
Titanophoneus PIN 157/1	ray IV	ray V	di V, little space
Estemmenosuchus PIN 1758/23	ray IV	ray V	di V, little space
ANOMODONTIA			
Suminia PIN 2212/62 (Fröbisch & Reisz 2011)	ray IV, ray V		di IV
Galechirus SAM-PK-1068	ray IV	ray V (me part)	di V, little space
Galechirus AMNH 5516			
Eosimops BP/1/6674	ray IV, ray V (me part)		
Robertia SAM-PK-11885a	ray IV		
Robertia SAM-PK-11885b	ray IV		
Diictodon CGS FL186	ray IV		space
Diictodon TM4991	ray IV, ray III (la part)		ur, little space
Diictodon UMZC T 420	ray IV, ray III (la part)		
Diictodon GPIT/RE/7193	ray IV, ray III (la part)		ur
Diictodon SAM-PK-K10699	ray IV, ray III (la part)		ur
Diictodon CGS RMS214	ray IV, ray III (la part)		ur
Diictodon CGS T72	ray IV, ray III (la part)		little space
Cistecephalus BP/1/2124	ray IV		ur?
Cistecephalus BP/1/2915	ray IV		
Kannemeyeria NHMUK R 3741			
Stahleckeria MCZ 1688	ray IV, ray V (me part)		di IV (la part), ur
GORGONOPSIA			
Arctognathus SAM-PK-3329	ray IV	ray V	di V
Aelurognathus SAM-PK-2342	ray IV, ray V (me part)	ray V	di IV+V

cf. *Cynariops* SAM-PK-K10000	ray IV	ray V (me part)	di V , probably space
Dinogorgon BP/1/2190	ray IV, ray V (me part)	ray V	di IV+V
Gorgonopsia indet. BP/1/1210	ray IV, ray V (me part)	ray V (la part)	di IV+V
THEROCEPHALIA			
Glanosuchus SAM-PK-K7809	ray IV, ray V (me part)	ray V	di IV+V, ur (?)
Glanosuchus SAM-PK-12051			
Glanosuchus CGS RS424	ray IV, ray V (me part)		di IV+V, ur
*Olivierosuchus*BP/1/3973	ray IV		big space
Olivierosuchus BP/1/3849	ray IV, ray III (la part)		
Theriognathus NHMUK R 5694	ray IV	ray IV, ray V (me part)	di V, ur not present
Ictidosuchoides CGS CM86-655	ray IV	ray V	di V, little space
?Ictidosuchoides BP/1/2294	ray IV, ray V (me part)		di IV(+V), little space
Tetracynodon AM 3677	ray IV		space
Microgomphodon SAM-PK-K10160	ray IV, ray III (la part)	mc V broken pr	
NON-MAMMALIAMORPH CYNODONTIA			
Procynosuchus BP/1/591	ray IV	ray V	di V, little space
Procynosuchus NHMUK PV R 37054	ray IV	ray V	di V, little space
*Procynosuchus*RC92	ray IV, ray V (me part)		di IV(+V), ur
Galesaurus BP/1/2513	ray IV		space
Galesaurus SAM-PK-K10465	ray IV		space
Thrinaxodon BP/1/1737	ray IV, ray V (me part)	ray V (la part)	di V, space?
Thrinaxodon BP/1/7199	ray IV, ray V (me part)	ray V	di V, space
Diademodon NHMUK R-3581	ray IV, ray V (me part)	ray V	di V, space
Diademodon USNM 23352	ray IV, ray V (me part)		big space (around di V(?))
Cynognathia indet. BP/1/4534	ray IV, ray V (me part), ray III (la part)		di IV, space
Exaeretodon PVL 2554	ray IV		space
Trucidocynodon UFRGS PV-1051T	ray IV		big space
MAMMALIAMORPHA			
Tritylodontidae indet. WCW-06A-34	ray IV, ray V (me part)		di IV, space
Bienotheroides IVPP V 7905	ray IV, ray V (me part)		di IV, space
Kayentatherium TMM 43690-5.136 (Hoffmann & Rowe 2018)			
Jeholodens GMV 2139a	ray IV		space
Zhangheotherium IVPP V7466	ray IV, ray V (me part), ray III (la part)		di IV, mc V?
Eomaia CAGS01-IG-1a	ray IV, ray V (me part)		di IV

Figure S1: Evolution of the intermedium shape in dorsal view and the intermedium loss, mapped on a compromise phylogenetic tree of Permian and Mesozoic synapsids.

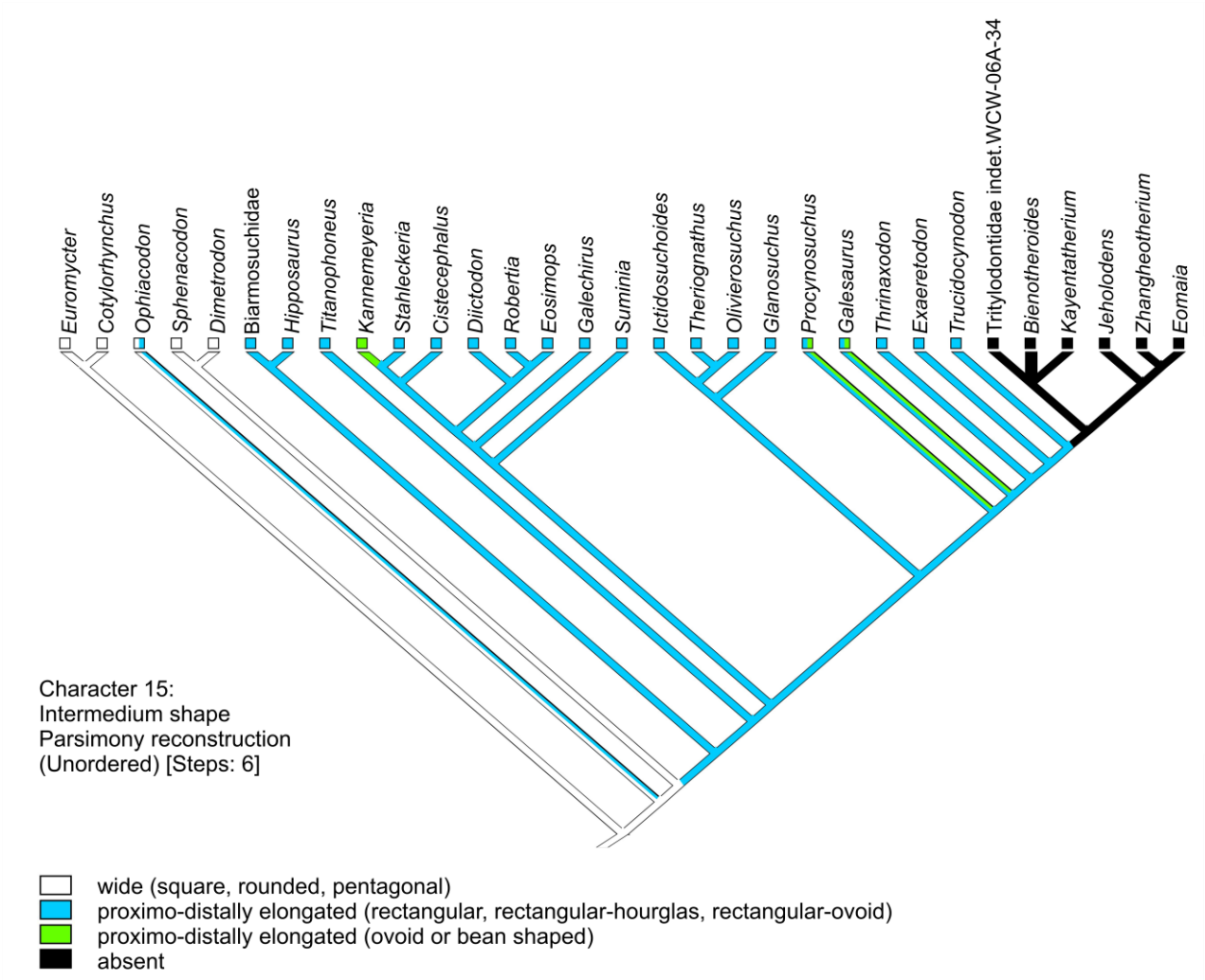

Figure S2: Position of distal carpal I, mapped on a compromise phylogenetic tree of Permian and Mesozoic synapsids.

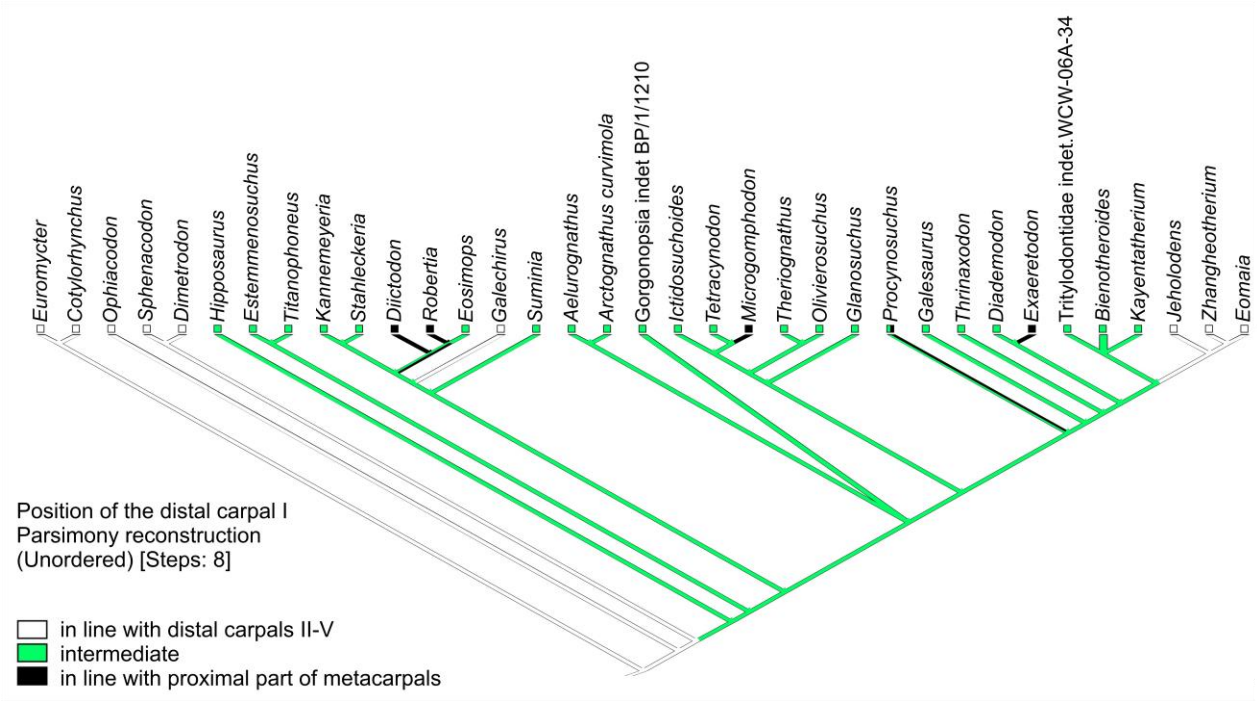

Figure S3: Conditions of the medial centrale, mapped on a compromise phylogenetic tree of Permian and Mesozoic synapsids. The fused state of the medial centrale and the radiale bears some uncertainty in *Thrinaxodon* BP/1/1737 and Cynognathia indet. BP/1/4534.