

-RXUQDO RI (QJLQHHULQJ 6FL

9ROXPH ,VXXH S

<http://doi.org/10.56958/jesi.2019.4.3.247>

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ZZZ MHVL DVWU UR

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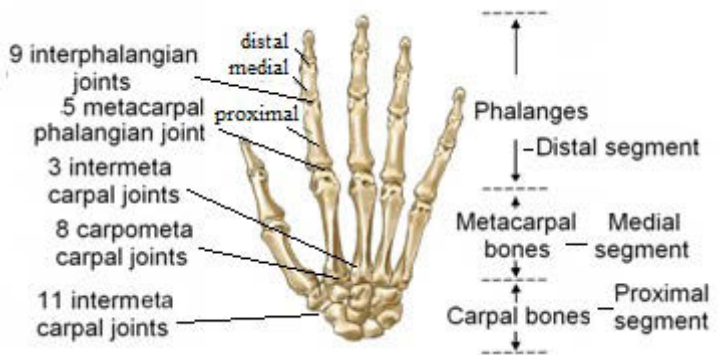
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GHSHQLQJ UHVHDFK WR EHWWHU XQGHUVWDQG V
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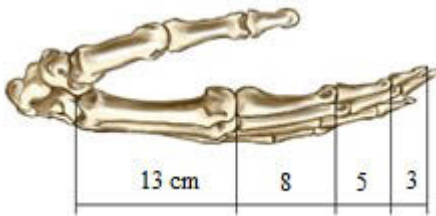
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UHODWLYH VL]H RI WKH GLIIHUHQW JURXS RI ERQ
SKDODQ[HV 7KXV WKH VNHOHWRQ RI WKH KDQG
JURXSHG LQWR WKUHH VWUXFWXUHV > @ WKH
ERQHV WKH PHWDFDUSDO ERQHV JURXS FRQVLVWL
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JHUV FRQVLVWLQJ RI IRU WKH WKXPE RU SKD
H[WHQVLRQ ZLWK D WRWDO RI HOHPHQWV ERQH



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ELRPHFKDQLVP KDV GLIIHUHQW GHJUHHV RI PRELO
WZH HQ WKH FDUSDO DQG WKH PHWDFDUSDO ERQH
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WR LQFUHDVHG JUDVSLQJ FDSDFLW\ DQG PLFURPD
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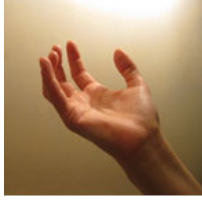
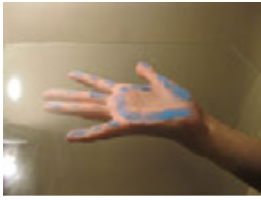
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&KDUDFWHULVWLF FRQILJXUDWLRQV RI WKH KXP

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HOHPHQWV ERQH V WKH QXPEHU DQG GHJUHH RI F
RI WKH YDULRXV FRPSRQHQWV RI WKH KDQG (YHQ
VXEMHFW > @ DQ\ QHZ DSSURDFK LV XVHI
IDU 7KXV WKH WUDQVLWLRQ IURP WKH IODW SDO
RFFXS\ UHODWLYH OLPLW SRVLWLRQV)LJ D WR
GXH WR UHODWLYHO\ VPDOO GLVSODFHPHQWV RFF
SRVLWLRQ RI WKH SDOP LV PDLQO\ WKH UHVXOW RI
UHODWLRQ WR WKH FDUSDO FRPSOH[)LJ REYLF
WKH ILQJHUV E\ WKH PRYHPHQWV RI WKH PHWDFDU
,W VKRXOG EH QRWHG IURP WKL VWDJH WKDW W
RI D VSKHUH ZKLFK LV QRW SRVVLEOH LQ WKH KDQ
WKH RUDQJXWDQ VHH)LJ E

6W DUHWX , 1HZ H[SHULPHQWDO DQG PLQLPXP PDW



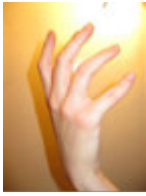
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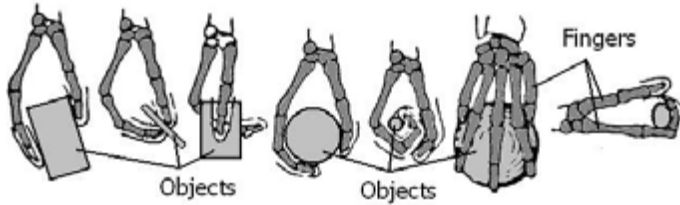
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)LJ 5HODWLYH SRVLWLRQV RI KDQG ERQH V IRU YDU

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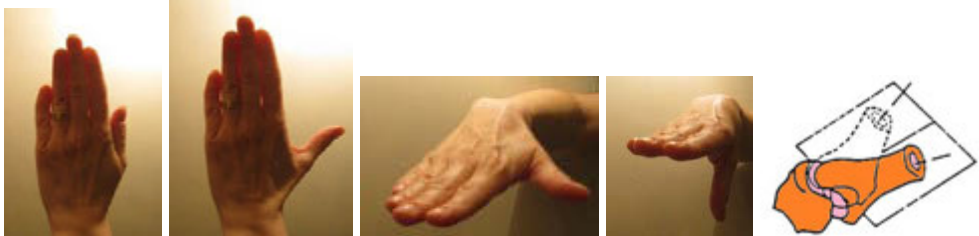


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D E F
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 DGGXFWRQ SRVLWRQV

7KH WKXPE KDV VSHFLILF PRYHPHQWV GXH WR WKH
 LV DOVR FDOOHG VDGGOH MRLQW GXH WR WKH K\SHU
 DQG > @



D E F



D E F

)LJ 7KXPE DEGXFWRQ ± DGGXFWRQ D E DQG UR

%HWZH HQ WKH SKDODQJHV WKH ILQJHU ERQH V W
 W\SH VHH)LJ F DQG G ,Q WKH SUR[LPDO LQWHU
 RI IOH[LQRQ H[FHHGV ž DQG WKDW RI GLVWDO LQW
 DQJOHV FKDUDFWHUL]LQJ WKH DPSOLWXGH RI WKH
 WKH ILQDO SRVLWRQ DUH VKRZQ LQ)LJ ,WV \
 SRVLWRQ WKH SKDODQJHV RI WKH ILQJHUV DUH L



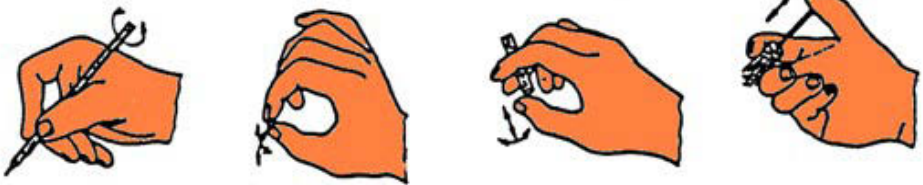
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GLPHQVLRQV RI WKH KDQG VNHQWRQ PDNH SRVV
WLRQV LQ JHQHUDO DQG RI JUDVSLQJ LQ SDUWL
DERYH LQ DGGLWLRQ WR WKH LPDJHV PDGH E\ WK
FRQILJXUDWLRQV RI WKH KXPDQ KDQG ZH DGGHG
VLWXDWLRQV VWXGLHG > @ ,W FDQ DOVR EH PHQW
DOVR WR WKH SURSRUWLRQV RI WKH FRPSRQH QW
ELOLWLHV WR DFKLHYH WKH GLVSODFHPHQW RI D
SODFHPHQW ZKLFK FDQ EH FRQVLGHUH G PLFURPD
WLRQV ZKHUH PLFURPDQLSXODWLRQ LV SRVVLEOH
FUHDWHG E\ WKH DXWKRU WKHQ VNHWFKHV WR ZK
WKDW FDQ EH LPSRVHG WR WKH REMHFV ZH JUDV



)LJ 3RVLWLRQV RI KXPDQ KDQG PLFURPDQLSX

\$V PHQWLRQH G DERYH WKH VWXG\ RI WKHVH VLWX
RI DQWKURSRPRUSKLF KDQG OLNH JULSSHUV XVH

3DUWLFXODULWLHV RI JUDVSLQJ ZLWK KXPDQ KD

*UDVSLQJ LV WKH PRVW LPSRUWDQW DFWLRQ WKH
DQG PRYH WKHP IURP RQH SRVLWLRQ WR DQRWK
GLPHQVLRQV DQG ZHLJKWV FDQ EH VDIHO\ JUDVSH
RI WZR ILQJHUV VPDOO HYHQ YHU\ VPDOO REMHF
([SHULPHQLQJ WKH SRVVLELOLWLHV RI KXPDQ KD
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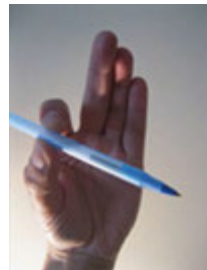
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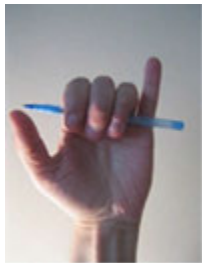


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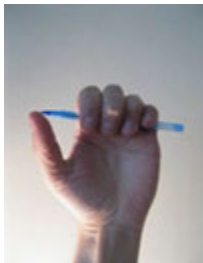
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)LJ

*UDVSLQJ VLWXDWLRQV RI D URG W\SH R

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ILQJHUV VHH FLG RUDZLWK WZR RU PRUH RSSRVDE
H[SHULPHQW LW LV VLJQLILFDQW WKDW RQO\ JULS
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*UDVSLQJ DQ REMHFW RI UDQGRP DQG VPDOO

)RU DQ DSSUR[LPDWHO\ VSKHULFDO VPDOO REMHFW
LW FDQ EH VHHQ WKDW LI WKHRUHWLFDOO\ JUDVSL
ILQJHU XS WR ILYH ILQJHUV EDVLFDOO\ JUDVSLQJ
WZR ILQJHUV VHH)LJ D E F ,W FDQ EH VHHQ
HQFRPSDVVLQJ ZLWK RQH ILQJHU DQG WZR RSSRVL
D DQG F WKH XVH RI RQH PRUH ILQJHU RU WZR
GXH WR WKH LPSRVVLELOLW\ RI FRQWDFW ZLWK WK

6W DUHWX , 1HZ H[SHULPHQWDO DQG PLQLPXP PDW

WR XVH RQO\ WZR ILQJHUV LQ D OLPLW FDVH RI W
UHGXQGDQF\ RI JUDVSLQJ



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)LJ



6LWXDWLRQV RI JUDVSLQJ D VPDOO REM



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*UDVSLQJ DQ REMHFW RI UDQGRP VKDSH DQG

,I WKH VL]H RI WKH JUDVSHG REMHFW LQFUHDVHV
ORQJHU SRVVLEOH WR JUDVS ZLWK RQO\ RQH ILQJ
WKUHH IRXU RU ILYH ILQJHUV KDYH DQRWKHU XWL
FDVH ZLWK DSSOLFDWLRQ WR D PRXVH W\SH REMHFW



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)LJ *UDVSLQJ VLWXDWLRQV RI DQ DYHUDJH VL

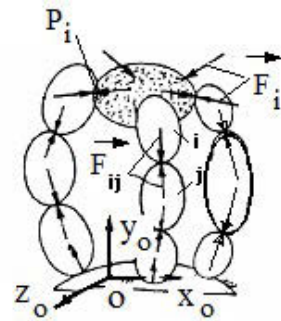
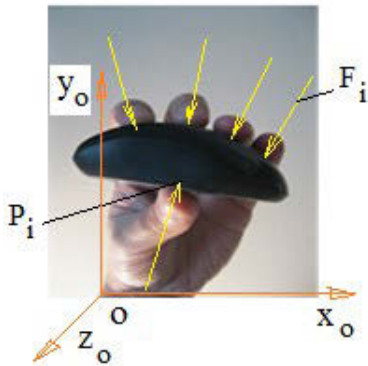
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RI)LJ DQG H

OLQLPXP PDWKHPDWLFDO FRQGLWLRQV IRU VWD

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PDWLFDO PRGHOLQJ RI JUDVSLQJ 7KXV IURP WKH
DV WKDW RLQZKLAK ZH UHSUHVHQWV DSG OLVKING FER QW
ILQJHUV DW WKHFRVWHDJWDSVSLQJVE3MHFW DFFRUG
WR WKH JHQHUDO FDVH RI D VROLG REMHFW JUDV
IROORZLQJ H[SODQDWLRQV DUH JLYHQ UHJDUGLQJ
VWDWLF JUDVSLQJ> @



D)LJ 1RQ GHIRUPDEOH VROLGV V\WHP

(TXLOLEULXP RI D 6ROLG %RG\ 6\WHP

,I D V\WHP RI QRQ GHIRUPDEOH ULJLG VROLGV L
H[WHUQDO IRUFHV) DQG UHDFWLRQV DQG LQWHUQDO
SOLQJ) LM 0 LM L • M z LM WKH EDODQFH FRQGLWLRQV
H[WHUQDO IRUFHV DQG LQWHUQDO DQG H[WHUQDO

$$\begin{matrix} \vec{0}_L^Q \\ \circ_L \end{matrix} \vec{)}_L \begin{matrix} \vec{0}_L^Q \\ \circ_L \end{matrix} \vec{)}_{LM} \\ \textcircled{R} \begin{matrix} \vec{0}_L^Q \\ \circ_L \end{matrix} \vec{)}_L \vec{)}_{LM} \begin{matrix} \vec{0}_L^Q \\ \circ_L \end{matrix} \vec{)}_{LM} \begin{matrix} \vec{0}_L^Q \\ \circ_L \end{matrix} \vec{)}_{LM}$$

ZKHUHQ DUH SRVLWLRQ YHEHQSV) FM LRUHV
\$ QXPEHU RI VFDODU OLQHDU HTXLOLEULXP HTXD
OLEULXP FRQGLWLRQV DORQJ WULGLPHQVLRQDO U
RU H[WHUQDO UHDFWLRQV WR WKH V\WHP

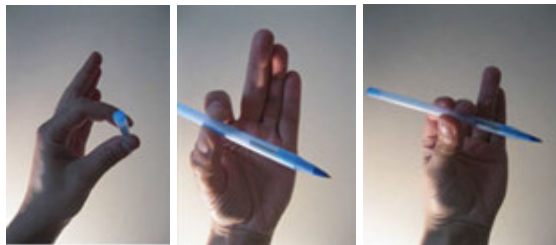
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OLQH DU PRYHPHQW
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LQGSHQGHQW OLQNV RI UDQN ZHUH XVHG WKH
WR D KRPRJHQHRXV V\WHP RI VL[HTXDWLRQV ZLW
WULYLDV VROXWLRQ REYLRXVO\ LQ VXFK FDVH
EOH 7KHUHIRUH WR DFKLHYH WKH HQWLW\ JULSS
F RI UDQN DUH QHFHVVDU\ LQGHHG LQ VXFK
WLRQ OHGTV WR D KRPRJHQHRXV V\WHP RI L
NQRZQV \$V D UHVXOW VL[RI WKH OLQN IRUFHV
IRUFH WKDW LV LQGHILQLWH LQGSHQGHQW WK
ODWWHU
6\QWKHWFDOO\ WKH QHFHVVDU\ DQG VXIILFLHQW
HULQJ RQO\ FRQWDFW IRUFHV FDQ EH H[SUHVVHG
\$Q HQWLW\ JULSSLQJ LQYROYHG FRQWDFW WLRQ
V\WHP RI D PLQNF&UDQNLQJ &

)HDWXUHV RI KXPDQ KDQG PLFURPDQLSXODWLRQ

([SHULPHQWLQJ PLFURPDQLSXODWLRQ RI D UR

\$V DQ H[DPSOH RI PLFURPDQLSXODWLRQ FKDUDFW
DUWLFXODWHG ILQJHUV LW LV VKRZQ WKH PLFUR
VLPSOH F\OLQGULFDO SHQ)LJ ,W FDQ EH QRW
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K\SRVWDVHV VHH DQG> @



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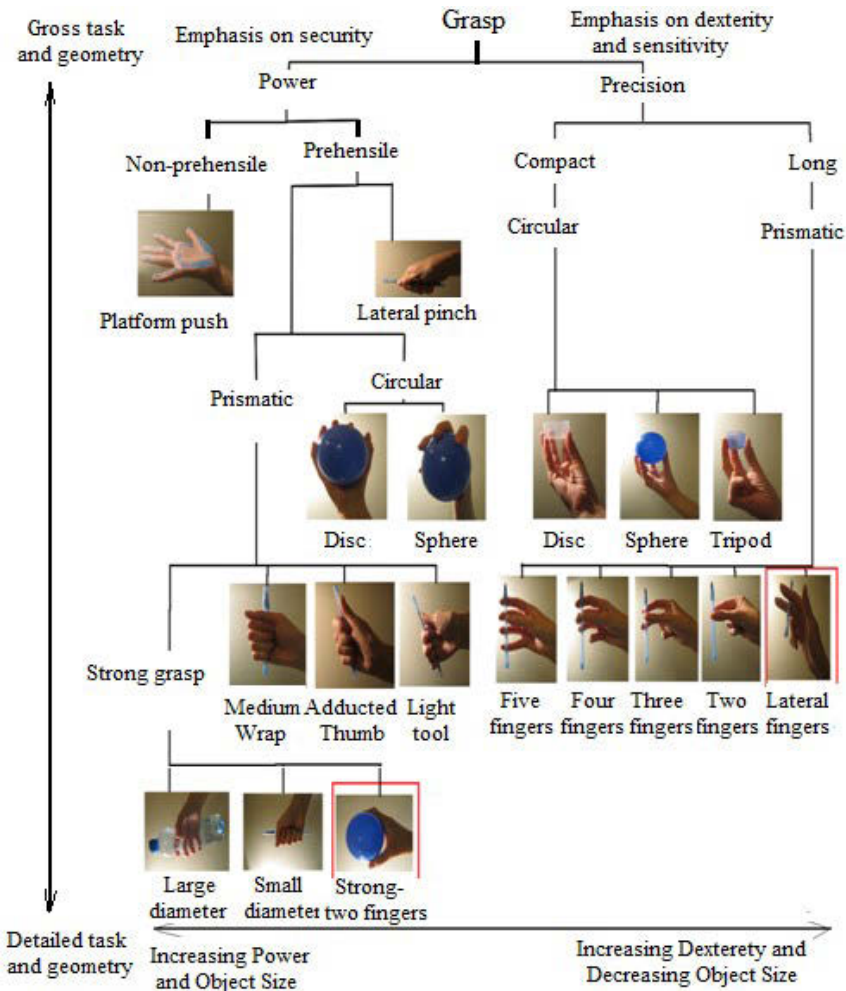
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&RQWULEXWLRQV WR H[SHULPHQWDWLRQ DQG H[

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JUDVSLQJ VLWXDWLRQV XVLQJ WKH KXPDQ KDQG SU
RWKHU VRPHKRZ VLPLODU DSSURDFKHV ZHUH D
V\VWHPDWL]DWLRQ LV SHUIRUPHG IURP WZR PDLQ
V\VWHPDWL]DWLRQ LV VKRZQ LQ)LJ DGDSWHG)
FRPSOHWHG ZLWK WZR VLWXDWLRQV QDPHO\ JUDV
SDOP H[WHQVLRQ DQG SRZHU JUDVSLQJ ZLWK WZR
ILQJHU RI WKH IRXU LQ WKH SDOP H[WHQVLRQ ZL
DYHUDJH WR PD[LXP GLHQVLRQV DERXW KDQG JU
DQG ILQJHU DELOLW\ WR HQFRPSDVV XVHIXO FRQW



)LJ &XWNRVN\ WD[RQRP\ DGDSWHG DQG H[WHQGHG XQG

6W DUH WX , 1HZ H[SHULPHQWDO DQG PLQLPXP PDW

\$OVR IRU VRPH RWKHU V\VWHPDWL]DWLRQ VRPHZ
QDPHO\ WKDW RI \RQV > @ WKHUH LV DQ DGDSWD



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)LJ \RQV V JUDVSLQJ VLWXDWLRQV DGDSWHG E

7KHVH ODVW WZR DGDSWDWLRQV DIWHU ZHOO NQR
UHVXPLQJ NQRZQ DVSHFWV ZKLFK E\ QHZ H[SHULP

&RQFOXVLRQV

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FDQ EH GUDZQ WKH KXPDQ KDQG KDV LWV VWUXFW
JRRG IXQFWLRQDOLW\ FRPSDUHG WR DOO RWKHU Q
RWKHU SULPDWHV HPSKDVL]LQJ VSHFLILF FRQILJ
PHQW LV XVHIXO DV VWXGLHV RI WKLV NLQG DUH
UHODWLYH GLPHQVLRQV EHWZHHQ WKH FRPSRQH
JUDVSLQJ RI REMHFWV RI YDULHG VL]HV DQG VKDS
RI VPDOOHU VHFWRQDO REMHFWV DQG ORQJHU

-RXUQDO RI (QJLQHHLQJ 6FLHQFHV DQG ,QQRYPD

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5HIHUHQFHV

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(GLWRUV

> @XPDU \$ 0XQGUD 7 +DQGXPDWLPLODEOH RQ KWWSV SGIV
RUJH GGF GHID H H D H SGI

> @D\ORU & / 6FKZD\$QDWRP\ DQG OHFKDQLF2/3R/LWBU\XPD
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RUJDO B B DVS

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> @WDUH\WXP HQWH GH URERWLF DL @HGRFFDQDQ L \$GRWHJ\DLHEU L

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SURWHJDUH(GL XRFREWL V %UDRY

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:RUNVKRS RQ +XPDQ 0RWLRQ \$XVWLQ 86\$

KWWSV LHH\SORUH LHH RUJ GRFXPHQ

> @SKH 7 1HXPQQ \$XPDLADQ@ ORGHOLQJ IURP' \$XUIDFH
3URFHGLQJV RI WKH V\PSRVLXP RQ ,QWHUIDFH 'JUDSKL

> @XULKDQD 7 0LRGWLQJ 'HIRUPDEOH +XPDQ +DQGV IUR
(XURJUDSKLFV \$&0 6,**5\$3+ 6\PSRVLXP RQ &RPSXWHU \$QLPDW
(GLWRUV *UHQREOH)UDQFH S

> @XVFKH\QYWOLFKH +IQGH .7@VWOLFVKH\$UHUOD\ +HUEHUW

> @KDQJ / < 0DWLQRPD WLF\$7KXPE ORGHGURBHMIGLQ&V RDQ@
,(((,QWHUQDWLRQDO &RQIHUHQFH RQ 5RERWLFV DQG \$XWRPD

> @DVKLPRWR + <DFRWD 6 &\$XJRLWDO LWDQK DWRKIDLPLF +XP
5HDO 7LPH 2SHUDWLRQ 0DNLQJ RI 'LJLWDO)LQJHU ZLWK 3DUW
RI WKH WK -RLQW &RQIHUHQFH RQ &RPSXWHU 9LVLRQ ,PD
\$SSOLFDFWLRQV 9,6,*5\$33 9ROXP *5\$33 5RPH ,WDO\

> @HUU - \$QDQWLV RI PXOWLWJHURERQGHV S ±

> @DOLVEXU\ .LGRWK%F DQG IRUFH DQDQ\VLV R\$DUWLFXOD
OHFK 7UDQVPLVV \$XWRP 'HVLJQ QR S ±

> @DNDVKLPD \$ 8QR 7 +D\DNDZD < .RQGRKHV6V ZD QDVDEOH
E\)RXU)LQJHUHG 5RERW +DQG IRU 3LFDQDQ\$DQDFPSRM\$XVPH
OHFKDWURQLF 6\VWHPV 0DUULRWV %RVWRQ &DPEULGJH &D

> @XWNRVN\ 0 2Q *UDVS &RQH W DQG WKH 'HVLJQ RI +DQG I
,(((7UDQVDFWLRQV RQ 5RERWLFV DQG \$XWRPDWLRQ QU

> @HL[7 5RPHUR - 6FKPLHGPD\HU +7KH '5\$33UDRQRP\UR
+XPDQ *UDVS(7SHUDQVDFWLRQV RQ +XPDQDFKQLQHS6\VWHPV

> @ROODU(QDQDWLRQ RI 'H[WHURXV 0DQSLXODWLRQDQDQDQW
KWWS FOHP GLL XQLVL LW aPDOYHJLL JUDVSTXDOLW\ ZS FR

> @LX -)HQJ) 1DNDPXUD\$7RQRPDQGHUHG\ 7UDVSV LQ
UHVHDFK LV VXSSRUWHG E\ 16) DZDUG ,6 6FKRRO RI

6W DUH WX , 1HZ H[SHULPHQWDO DQG PLQLPXP PDW

8QLYHUVLW\)RUEHV \$YH 3LWWVEXUJK 3\$
KWWS ZZZ FV FPX HGX a\QDNDPXU SDSHUV 7D[RQRP\YHU\GD
> @RQV \$ VLPSOH VHW RI JUDVSV3URFHGHQJWJRXV K(DQGQWH
&RQIHUHQFH RQ 5RERWLFV DQG \$XWRPDWLRQ 6W /RXLV 02